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ARTIFICIAL MANURES,

HOW TO

MAKE, BUY, VALUE, AND USE.

BY

ALFRED SIBSON, F.C.S.

NEW EDITION, GREATLY EXTENDED.

LONDON:
WILLIAM RIDGWAY, 169, PICCADILLY, W.
1878.

ARTIFICIAL MANURES,

HOW TO

MAKE, BUY, VALUE, AND USE.

GIVING THE COMPOSITION OF THE VARIOUS MANURES AT PRESENT IN USE, AND THE MATERIALS USED IN THE PREPARATION OF THOSE MANUFACTURED, WITH RECIPES FOR THEIR ADMIXTURE, ETC., WITH HINTS FOR THEIR EFFECTIVE AND ECONOMICAL EMPLOYMENT IN THE FIELD.

BY

ALFRED SIBSON, F.C.S.,

Author of "Agricultural Chemistry," "Every-day Chemistry," "Food, Feeding, and Manure," "A Lecture on Superphosphate," &c. Late (for eight years) Assistant Professor of Chemistry in the Royal Agricultural College, Cirencester, and First Assistant in Dr. Voelcker's Private Laboratory. Formerly Student of the Royal College of Chemistry and the Birkbeck Laboratory of University College.

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INTRODUCTORY REMARKS.

As the use of artificial manures is still extending, and as chemical analysis is correctly looked upon as the chief means of arriving at their value, a plain and reliable guide is often called for to enable practical men to understand analysis when put before them, and to enable them to obtain the full benefit which a knowledge of the materials at their command is capable of conferring.

To this end the following pages have been written, and which it is hoped will supply in a condensed form much of the information likely to be useful in connection with the subjects referred to, and in the treatment of which I have had in view the questions constantly put to me by buyers and sellers of manures, and the raw materials used in their preparation. Of the latter, only those in actual use or of particular interest, have been spoken of, so as to avoid needless amplification. I have also embodied some of the remarks and hints which have appeared in my annual reports, which I

have reason to know have been valued by a large circle of clients, though never before published.

I may add that the various recipes given are the same for which I have hitherto charged my usual fees, and are not inferior to others for which much larger sums have been paid; but as the present is the age of publicity, I now offer them free of cost to those interested, hoping to receive compensation in the same manner.

This pamphlet, although founded on the one bearing nearly the same title which I issued a few years since, has been greatly extended, and for the greater part re-written.

11, Eaton Terrace,
St. John's Wood, London.

ARTIFICIAL MANURES.

CHAPTER I.

MAKING MANURES.

BEING frequently applied to by intending manufacturers and farmers for directions for making superphosphate and other artificial manures, the following pages contain in a concise form the substance of my replies, with such remarks and extensions as have occurred to me as I proceeded. To persons also who are already well able to make manures satisfactorily, it is hoped they may not be without interest although some of the matter will necessarily be to them familiar.

In thus treating publicly of the preparation of superphosphate and other manures, I am betraying no trade secrets since the materials of which they are composed are now perfectly well known, and may be bought in large or small quantities; and as the process of manufacture is simple, any one may now make

the manures he requires in preference to buying them if so disposed: whether or not it is on the whole advisable to do so will be discussed hereafter.

In making such manures we require chiefly raw phosphatic materials, raw nitrogenous materials, and sulphuric acid or oil of vitriol. The list of the former from which to choose is now extensive since we have not only the older sources of phosphates, such as bones, bone ash, and phosphatic guanos, but also all the mineral phosphates of various degrees of merit, and which, although generally considered inferior to bone, as of course they are in the shape of insoluble phosphates, are yet in every respect as good when dissolved, as sources of soluble phosphate.

Nitrogenous materials also are numerous and of widely differing value, but whereas new deposits of phosphates are constantly being discovered, new sources of nitrogen, at least of any extent, are very limited, and hence these materials are naturally and commercially of higher value than the foregoing. The same is true of those materials which supply both nitrogen and phosphates, such as bones, guano, dried fish, &c. All the raw phosphatic materials used for dissolving contain phosphate* of lime (tribasic phosphate of lime) in its natural or insoluble state associated

* This form of expression is retained throughout, as "tricalcic phosphate," "ammonium sulphate," "sodium nitrate," &c. are at present unknown in commerce.

with various impurities, the principal of which are carbonate of lime, earthy or silicious matters, oxide of iron, and sometimes alumina. The value of these materials depends mainly on the percentage of tribasic phosphate of lime they contain.

The original idea, due to the late illustrious Liebig, was to render bones more efficacious as manure by dissolving in sulphuric acid; from this a natural extension would lead to bone ash, and afterwards to the mineral phosphates. The improvement thus effected in bones was so striking as to lead to the rapid extension of the manufacture of these vitriolized bones, as they were at first termed, and which with the various other kinds of superphosphates now produced, have almost superseded the use of bone dust in its natural state, except for special purposes. Bones are at present too scarce and dear to allow of being used alone for making superphosphate, although still largely employed in conjunction with bone ash, &c. for making the dissolved bone manures, which, when of good quality, are now amongst the best phosphatic manures at the command of the agriculturist.

The quantity of bones moreover now obtainable in commerce would not suffice to make a hundredth part of the superphosphates now required, hence the discovery of the mineral phosphates must be considered as an invaluable acquisition. These materials are supposed to be of animal origin, though of a very remote date;

in the case of coprolites (or dung stones) this is evident, but in some other cases, conjectural only; the probability is that most of the rocky deposits of phosphates are derived from beds of guano more or less altered by the action of water, heat, or pressure. The phosphatic guanos are of comparatively recent date, and are often unmineralized. These are in most cases guano deposits from which the soluble constituents, the nitrogenous compounds, &c., have been removed by rain, and are, in fact, the natural condition to which the richest guanos would soon become converted unless deposited in a situation almost free from rain, as in the case of the Chincha Islands (now exhausted) and adjacent localities. The great bulk of the excrementitous matter deposited by sea birds is thus washed back into the sea by rain before it has time to consolidate into guano.

In making superphosphates on the large scale it is of course the practice to purchase the phosphates in large quantities, generally by the shipload, in their natural state, and to grind them in mills specially arranged for the purpose. The process of grinding these articles is an expensive item, as they are mostly very hard and require to be ground to a powder almost as fine as flour, the same kind of stones being in fact used. Much of the art of using the mineral phosphates to the best advantage consists in the grinding, and it is only of late years this has been properly understood.

It is also an obvious advantage, and is the practice at many large manure works, to prepare the sulphuric acid required for dissolving the phosphates. As regards this process, and also the arrangement of the machinery and apparatus employed in the process, any detailed description would be out of place in a paper of this kind, but the following general sketch may perhaps be of service.

In the process of making sulphuric acid or oil of vitriol, sulphur or brimstone, or pyrites, (which contains this body in combination with iron, &c.) are burnt in ovens or "burners" with limited access of air, and the fumes of sulphurous acid thus produced, after admixture with nitrous acid gas (obtained by the action of strong sulphuric acid upon nitrate of soda) conducted into large leaden chambers into which steam is also passed. The sulphurous acid (the gas produced on striking brimstone matches) is under these circumstances converted into sulphuric acid which condenses with the steam at the bottom of the chambers (they are usually arranged in pairs) to form liquid sulphuric acid, but it requires a further process of concentration and distillation to become oil of vitriol. For dissolving phosphates the acid is usually employed directly from the chamber, having a specific gravity of about 1·55—1·60. The strength of sulphuric acid so prepared depends on the amount of real sulphuric acid present in it as indicated by its specific gravity or its

weight compared with water, acid of specific gravity 1·5 being half as heavy again as water. The strongest oil of vitriol has a specific gravity of about 1·84 or nearly twice as heavy as water. The acid commonly employed for dissolving phosphates when purchased is that known as brown acid and has a specific gravity of about 1·70 to 1·75.

For practical purposes the strength of acid is generally ascertained by the hydrometer arranged for "Twaddle's" scale, although less accurate than when obtained by direct weighing. The use of this instrument depends on the fact that the denser or heavier a liquid, the higher a body floats in it, just as a piece of iron will float on the fluid metal mercury, the latter being heavier than the iron. Hence the higher out of the liquid the hydrometer floats, the stronger the acid as shown on the graduated stem.

The most expensive item in the making of sulphuric acid is the nitrate of soda which as well known is generally worth about £15. to £18. per ton. Theoretically the nitrous gas is used over and over again, it acting as a go-between to induce the oxygen of the air to combine with the sulphurous acid and convert it into sulphuric acid. In practice there is found to be a loss more or less according to the care bestowed by the attendants; about 5 to 7 per cent. being the average loss; but which may reach any figure under careless management. It is for this reason mainly, that it does

not pay to make acid on the small scale; careful and trustworthy men, who must of course be well paid, being indispensable unless a wholesale loss from this source is to be experienced. An improved arrangement for passing the gases through a "Gay Lussac," and "Glover" towers (named after inventors) is now in use at the best works, for reducing this loss to a minimum.

The pyrites usually contain about 45 per cent. of sulphur of which about 40 should be available, that is not more than 5 per cent. should be left in the cinder or burned residue (less is often obtained). A larger quantity than this left in indicates mismanagement and is of course a waste.

The proportion of real sulphuric acid in acids of different strengths is found by reference to a table (Ure's) found in most chemical books, and which gives the percentage of dry acid as well as of oil of vitriol (o. v.) Thus we find that brown acid of specific gravity 1·75 has about 83-84 per cent. of o.v. and about 68½ per cent. of anhydrous acid. Brown acid is more commonly found to have a specific gravity of 1·70-1·71 and then has 80 per cent. o.v. and about 65 of dry acid. Chamber acid has commonly a specific gravity of about 1·60 and has 70 per cent. o.v. or 57½ per cent. of dry acid. From these data it can be easily calculated how much of one sort must be used to replace a given quantity of some other.

A useful rule for finding the relation between Twaddle's scale and the specific gravity, is to multiply the figures of Twaddle by 5 and place one unit with decimal point in front; thus, 1·50 multiplied by 5 equals 750, to which we add 1· making 1·750.

Brown acid by Twaddle being 1·50, and chamber acid 1·20. If it is wished to find the strength by Twaddle from the specific gravity, we of course do the converse of this, or divide the specific gravity by 5, omitting the unit and adding a nought, thus 75 divided by 5 gives 15, which with a nought makes 150.

In making surperphosphates on the large scale the mixing of the phosphate and acid is effected by steam power, the operation being carried on in a large vessel or "mixer" placed sometimes horizontally, sometimes diagonally at a greater or less angle, and having an axle passing through its length, on which a number of arms or stirrers are spirally placed, the object in view being by the revolution of the axle to effect a complete stirring up or commingling of the materials contained in the vessel. In some works we find a continuous process adopted, in which the materials to be mixed enter at the top of the mixer, (then placed in an inclined position,) and after passing down its length, are discharged at the bottom. In the more general plan we find an intermittent process employed, successive batches or mixings being placed in the mixer, and after complete agitation for 2 or 3 minutes the whole discharged.

Again in some works we find the mixer elevated some distance from the ground, the product being allowed to fall into a large walled enclosure or "den." In other cases it is placed on the ground level, the product being received in pits excavated in the ground. From these remarks it will be seen that no precise rules are followed — in fact scarcely any two works, either vitriol works or manure works, are alike, the only general rule, which however does not always appear to be had in view, is to make the most of the situation and means at command, so as to economise time and labour to the fullest extent consistent with efficient working.

For making on the small scale, the phosphates should be bought ready ground, and the acid obtained as "brown acid," in carboys holding about 150 lb. each, the mixing being effected in strong wooden troughs, about 9 ft. by 4 ft. by 3 ft., pitched inside, and thoroughly stirred by a wooden rake.

On mixing the phosphate with the acid, a brisk action at first ensues, owing to the liberation of carbonic acid gas, &c., but after a few minutes' stirring it subsides, and the creamy fluid gradually thickens and dries up, until in about twenty-four hours, if properly made, it is sufficiently solid to allow of being removed if necessary.

The proportions in which to mix the materials are varied somewhat by different makers, but the following

proportions are well adapted for making either on the large or small scale.

For a good mineral superphosphate :—

20 cwt. of Cambridge Coprolite.
17 ,, Brown acid.
3 ,, Water.*

This mixture should yield 25 to 28 per cent. of soluble phosphate, and 5 to 8 of insoluble phosphate, the coprolite having about 5—8 per cent. of tribasic phosphate of lime, and the acid a specific gravity of 1·71-1·72. The same proportions may be used for other mineral phosphates, or mixture of phosphates, using a little less acid for those with less carbonate.

For a bone superphosphate :—

6 cwt. Half-inch Bones.
14 ,, Cambridge Coprolite.
16 ,, Brown Acid.
3 ,, Water.
2 ,, Gypsum.

This mixture should yield 23 to 25 per cent. of soluble phosphates, and 7 to 11 of insoluble, the greater part bone, and about 1 per cent. ammonia (nitrogen equal to). The quality of this mixture may be raised by increasing the proportion of bone, and lessening somewhat the acid. 10 cwt. of bone and 10 cwt. mineral give a rich bone manure, yielding 1½

* A gallon of water weighs about ten pounds.

to $1\frac{3}{4}$ per cent. of ammonia; or bone ash may be substituted for the mineral phosphate. In mixing bone manures, it is a good plan to mix the mineral phosphate and acid first, and add the bone after—this gives the mineral the full benefit of the acid. A little animal matter, such as hair or wool, dried fish or blood, adds considerably to the quality of manure of this kind.

For commercial purposes, it is hardly possible to make a satisfactory bone manure from bones and acid alone (without bone ash), for reasons mentioned under "buying"; a recipe for one for home use is given a page or two hence.

For a concentrated bone ash superphosphate:—

20 cwt. Bone ash.
16 „ Brown Acid.
$2\frac{3}{4}$ „ Water.

This should give 35 to 40 per cent. soluble phosphates, the ash having 70 to 75 per cent. tribasic phosphate of lime, and 3 to 6 of insolubles.

Other phosphates than those above named, are of course equally suitable. A good practical rule as to the quantity of acid to be used is to give the phosphate or mixture of phosphate as much acid as it will take up to dry properly; it is bad policy to stint acid, since the value of the soluble phosphate is greater than the acid required to make it all soluble (as far as practicable), and it is impossible to do this without

enough, or more than enough, theoretically. In fact, by sending out undissolved phosphates in manure (except in the case of bone and some few other materials), we are wasting our raw phosphates, as although they cost as much as that portion which is dissolved, they have little or no practical effect in the field.

As a general rule, the water should be added to the acid in preference to the phosphate; it should be carefully mixed with a portion of the acid and well stirred, and the whole afterwards added, otherwise the water will not be equally distributed, and its being so is one of the chief points of success. It is less trouble to add the water to the phosphate, and afterwards the acid, but in this case the action is more violent, and the product does not dry so well. A common source of inequality in the product when making on the larger scale, is the varying strength of the acid as drawn off from the chambers, in which it has been proved to lie in layers of different strengths, an effective means of thoroughly mixing and testing the acid before use is indispensable for obtaining an uniform quality of manure.

In making superphosphate and similar manures, it must be borne in mind that the proportions of materials is but one element of success, hence I do not guarantee the above results. It is also scarcely possible to make at once a superphosphate which shall

be entirely satisfactory, but a few well-directed practical trials will generally indicate the best mode of employing the means at our command, and be more effectual than any elaborate directions, which however detailed, can never at once ensure success. The difficulty more commonly met with arises from the product not drying well, but when made for home use this may be avoided by the free use of drying materials. The above recipe, however, with common care and judgment, will not need any assistance in this way. A little more water may be used, if preferred, but the soluble phosphate will be lowered thereby.

The value of the superphosphate thus obtained depends chiefly, as well known, on the amount of soluble phosphate it contains (apart from any nitrogen), the object in view being to decompose or render soluble as much as possible of the phosphate of lime present; or, in other words, to leave as little as possible of the original phosphate unchanged by the acid; as this latter appears in the analysis as insoluble phosphate, and has of course, much less value. The theory of the process is simple, and may be thus described: the natural phosphate of lime as it occurs in all the raw phosphates presently to be named, is composed of three equivalents or portions of lime and one of phosphoric acid (hence the term *tri*basic), and in this state is *insoluble* in water, or remains unaltered in that liquid. The sulphuric acid added, being a stronger acid than

phosphoric acid, takes away two of the three equivalents of lime to form sulphate of lime, leaving the phosphoric acid combined with the remaining one equivalent of lime to form "biphosphate" of lime or "monophosphate" of lime, which is *soluble* in water, that is to say, dissolves or goes out of sight in water just as sugar or salt does. The soluble phosphate signifies the amount of the tribasic or natural phosphate of lime thus decomposed by acid. In superphosphates this natural phosphate of lime is also sometimes called "bone earth," because it is the characteristic constituent of the bones of animals.

Soluble phosphate may be rendered visible, and its characteristic property demonstrated, by a simple yet interesting experiment, which can be made as follows, without any chemical apparatus or materials:—A little superphosphate (say a teaspoonful), is mixed with water (about a wineglassful) in a tumbler, and stirred with a lead pencil. The soluble phosphate dissolves in the water, although no change is seen, in consequence of the insoluble matter also present, but if we remove this latter by straining, we may get a clear solution of the soluble phosphate in which its presence may be made manifest. The straining in this case can only be done by filtering, and to do this we take a piece of blotting paper (white paper in preference) about six inches square, and fold it double, and again double at right angles, so that on opening one side we get a cone or kind

of cup, into which the above muddy liquid may be poured without running over the edges; this may be supported in the mouth of a tall ale glass. The liquid that passes through the paper should be as clear and bright as the water at first used (a *solution* signifying a liquid in which a solid is taken up invisibly, except in the case of coloured substances) and if not so must be rendered clear by re-filtering (through the same filter). This clear liquid contains the soluble phosphate, which may be rendered apparent by adding a little washing soda previously and separately dissolved in a little water; the white gelatinous substance so produced is the soluble phosphate again rendered insoluble by the soda, and may be collected in the solid form on another filter as above, and on which we may have some further remarks to offer presently. From the above experiment we may also form an idea of the principle on which superphosphates are analysed; by taking a weighed quantity to begin with, and weighing the soluble phosphate obtained, by suitable apparatus, the chemist is enabled to arrive at the percentage of the bone earth made soluble.

CHAPTER II.

PHOSPHATIC MATERIALS.

The following tabular statements represent the composition of the principal phosphatic materials at present used for dissolving purposes in the preparation of superphosphates, &c., and are stated in the manner I adopt in my ordinary certificates, and which is similar to that employed by most other analysts. The examples chosen are taken as fair examples of the materials mentioned from a very large number I have analyzed; a much larger number might of course be quoted were it desired to amplify the subject.

Composition of various Coprolites.

	Cambridge. Good.	Ditto. Low.	Bedford.	Boulogne.	Wicken.
Moisture	1·24	·70	2·06	1·90	1·20
*Phosphoric acid . .	26·80	24·90	23·52	20·80	20·80
Lime	43·26	42·16	33·46	31·94	32·18
Carbonic acid . .	7·10	5·04	...	3·80	3·82
Equal to carbonate of lime . . .	16·13	... 11·45	...	8·65	... 8·68
Other constituents (not determined) . .	12·70	15·07	16·54	15·02	19·50
Insoluble silicious matters	8·90	12·13	24·42	26·53	22·50
	100·00	100·00	100·00	100·00	100·00
*Equal to tribasic phosphate of lime . .	58·50	54·36	51·34	45·41	45·41

Composition of:

	Suffolk Coprolites.	Aruba.	Alta Vela.	Rodonda.
Moisture . . .	1·03	11·53	16·50	21·13
*Phosphoric acid . .	25·50	29·50	27·20	30·24
Lime	37·24	42·06	8·93	3·16
Carbonic acid . . .	3·60	5·35		
Equal to carbonate of lime	8·18 ...	12·16		
Other constituents . .	20·50	10.93	26·23	24·84
Insoluble silicious matters .	12·13	·63	21·14	20·63
	100·00	100·00	100·00	100·00
*Equal to tribasic phosphate of lime	55·67	64·40	59·38	66·01

This sample of Alta Vela contained oxide of iron 7·20, and alumina 14·16. The Rodonda contained 3·64 of oxide of iron and 15·72 of alumina.

Composition of:

	Spanish. High.	Portuguese. Low.	Navassa.	Canadian.	German.
Moisture	Traces	1·30	2·63	Traces	1·30
*Phosphoric acid . .	33·60	24·90	33·10	35·30	28·02
Lime	42·02	36·16	38·27	47·22	37·11
Carbonic acid .	...	3·12	...	1·36	2·76
Equal to carbonate of lime . . .	...	7·10 ...	...	3·10 ...	6·30 ...
Other constituents (not determined) . .	8·11	13·30	22·74	10·62	12·68
Insoluble matter . .	16·27	21·22	3·26	5·50	18·13
	100·00	100·00	100·00	100·00	100·00
*Equal to tribasic phosphate of lime . .	73·35	54·35	72·26	77·06	61·17

South Carolina Phosphates.

	1.	2.	3.	3.	Land Rock.
Moisture	·64	2·02	1·04	9·20	5·04
*Phosphoric acid . .	27·30	26·80	25·70	23·90	25·81
Lime	39·12	39·20	37·38	35·14	37·34
Carbonic aci . .	...	3·34	...	2·94	3·01
Equal to carbonate of lime . . .	...	7·60 ...	...	6·70 ...	6·80 ...
Other constituents (not determined) . .	21·14	14·70	16·76	9·72	14·48
Insoluble matter . .	11·80	15·94	19·12	19·10	14·33
	100·00	100·00	100·00	100·00	100·00
*Equal to tribasic phosphate of lime . .	59·60	58·59	56·10	52·17	56·32

Curaçao Phosphate and Guano.

	No. 1.	No. 2.	Guano.
Moisture	·43	·40	10·10
*Phosphoric acid	39·50	40·50	33·70
Lime	49·76	50·97	45·63
Carbonic acid	3·30	1·60	1·93
Equal to carbonate of lime	7·50 ...	3·63 ...	4·41 ...
Other constituents	6·69	6·29	7·96
Insoluble matter	·32	·24	·67
	100·00	100·00	100·00
*Equal to tribasic phosphate of lime	86·23	88·41	73·60

French Phosphates, etc.

	1.	2. Low.	Mexillones Guano.	Sombrero.
Moisture	2·01	5·80	9·57	6·50
*Phosphoric acid	34·88	25·40	32·38	31·60
Lime	45·33	33·16	42·15	44·67
Carbonic acid	2·77	3·65	1·41	...
Equal to carbonate of lime	6·30	8·30	3·20	...
Other constituents	11·45	12·86	11·14	15·99
Insoluble matter	3·56	19·13	3·40	1·24
	100·00	100·00	100·00	100·00
*Equal to tribasic phosphate of lime	76·11	55·45	70·70	68·98

Bone Ash and Bone Black.

	1.	2.	3.	Black. 1.	Black. 2.
Moisture	2·54	6·10	8·03	...	...
*Phosphoric acid	30·20	33·28	30·50	30·78	36·80
Lime	40·31	41·13	44·67	...	...
Carbonic acid	2·68	2·24	2·68	...	...
Equal to carbonate of lime	6·10	5·10	4·60	...	...
Other constituents (not determined)	11·67	6·75	4·60	...	..
Insoluble matter	12·60	10·50	5·52	...	...
	100·00	100·00	100·00		
Equal to tribasic phosphate of lime	65·93	72·10	76·90	67·20	80·34

Animal Charcoal (so called).

Carbon and traces of moisture	52·50
Oxide of iron and traces of phosphates . . .	8·22
Carbonate and sulphate of lime	9·11
Insoluble silicious matter	30·17
	100·00

The above may be termed an imitation bone black, several samples of which have been submitted to me. Although this material (which I believe is prepared from shale) possesses some decolorizing power, it is for dissolving purposes quite valueless, and buyers of animal charcoal should therefore be on their guard against it.

Cambridge Coprolite—is the best known, and until lately perhaps the most extensively used phosphate, and which on account of the light and porous superphosphate it yields, is deservedly a great favourite. It occurs in small bluish grey nodules, the better samples being those in which the nodules are largest. Of late years, either from the upper and superior deposits being exhausted, or, as asserted by some persons, through a want of care in the washing, they do not yield so high a percentage of phosphate of lime as formerly. As in most phosphates also the lower percentage is not proportionately so good as the higher, being generally accompanied by a higher percentage of oxide of iron which deteriorates the product: Cambridge coprolite

however contains less of this objectionable constituent than most other coprolites.

BUCKINGHAMSHIRE COPROLITE—is a variety somewhat similar to the above, but often contains much larger nodules, and these yield 64 and 66 per cent. of phosphate of lime: there appears to be only limited supplies of them.

SUFFOLK and BEDFORD COPROLITES—are of a reddish brown colour, and contain more oxide of iron than the foregoing, yet when of good quality, and yielding about 56 per cent. of phosphate of lime, are useful materials, more especially for use in conjunction with other phosphates. The same may be said of the "red" and "black" Wicken coprolites, which contain from 40 to 50 per cent. phosphate of lime.

FRENCH or BORDEAUX PHOSPHATE—has been very largely used in the phosphate manufacture, as one of the best and cheapest materials, but at present appears to be getting scarce. There are several qualities, ranging from 50 to about 76 per cent., the latter allowing of high qualities of superphosphates being made from it. The lower qualities contain much clay and oxide of iron, and are of much less value per unit than the higher.

SOUTH CAROLINA PHOSPHATE—is now very largely employed, and more liked as it becomes better known. It contains but little carbonate of lime and oxide of iron, and allows of a high proportion of soluble phos-

phate being obtained from it with a comparatively small expenditure of acid. The "River rock" is that principally used, and is of a dark grey colour of various shades and qualities, as shown in the above table. It possesses one great advantage over most other phosphatic materials, viz., that the lower qualities are as valuable per unit as the higher, since the inferiority is only due to a little additional sandy matter, which leads to no waste of acid nor prevents the phosphate present being properly decomposed.

The "LAND ROCK" is of a lighter and browner colour, and is also a nice material, but the supplies of it appear to be much more limited.

CURACAO PHOSPHATE—is a very high-class phosphate lately introduced, the merits of which will be seen at a glance from the analyses quoted, which are of cargoes recently sold. It is specially adapted for making high qualities of superphosphates, for which it commands a high price: also for other purposes, being the purest form of phosphate of lime in commerce, excepting perhaps the best picked bone ash.

CURACAO GUANO—has been largely used, especially on the Continent, being suitable for use either in an unprepared state as a superior phosphatic guano, or for dissolving purposes, and possesses great merits as a source of pure phosphate of lime. It consists of phosphate of lime in an unmineralized state and in a fine state of division, with but little carbonate of

lime, and almost entirely free from oxide of iron, alumina, and silicious matters: it ranges in quality from about 65 to 75 per cent. of tribasic phosphate of lime.

MEXILLONES GUANO—is another high-class phosphatic guano, having about 70 per cent. phosphate of lime in an unmineralized form, with little carbonate, oxide of iron, or sand. It has a fine reddish brown colour, due to organic matter, and not ferruginous compounds, as might be supposed.

PORTUGUESE AND SPANISH PHOSPHATES—are used to a considerable extent, and would be much greater, but the supplies appear to be limited: it is much liked for special purposes, and ranges from about 57 to 71 per cent.; it contains but little oxide of iron, but a good deal of silicious matters.

NAVASSA PHOSPHATE—is also a useful phosphate for special purposes, and has lately yielded several samples giving over 70 per cent.

SOMBRERO PHOSPHATE, GERMAN PHOSPHATE, CANADIAN PHOSPHATE, &c., are also employed for dissolving purposes, but require no special comment.

BONE ASH, as well-known, is imported from South America, and is always a favourite phosphatic material being easier of conversion into superphosphate than most other materials, and when of high quality, yields proportionately high superphosphates. It occurs of all qualities, the average being about 70: dry and clean

samples being higher, and damp and dirty ones of course lower.

Bone Black or Animal Charcoal is also a favourite material, though obtainable only in comparatively small quantity. The primary use of this material is, as well-known, for the decolorizing of raw sugar, when newly made the siftings only are used for dissolving purposes, and afterwards the whole material when it admits of no further renewal.

Another kind of phosphate of a different nature to the foregoing has from time to time appeared in the market, viz., the Phosphates of Alumina, of various qualities, of which the Rodonda phosphate and Alta Vela are best known. These materials consist in reality of phosphate of alumina and iron, with little lime, and have not up to the present received a wide application in the manure trade. Although of course inferior to phosphate of lime, and likely to remain in the background while the latter is plentiful, the doctrine promulgated by some chemists that phosphoric acid in this shape is useless for agricultural purposes is a mistake, for the reason that in all naturally fertile soils the phosphoric acid exists in the shape of phosphate of iron and alumina, and also that these bases have the power of decomposing any soluble or gelatinous phosphate of lime which may be added to ordinary soils as manure. I may also add that I have met with some very marketable samples of manures

made from these phosphates, and which were also reported well of in the field, and by those who were ignorant of their composition.

It will be seen that all these materials have been analysed by determining the phosphoric acid, from which the tribasic phosphate of lime is calculated, this being now recognized as the only correct means of arriving at their value. The oxide of iron and alumina can be estimated in these materials when desired, but it is not possible to determine with certainty, as sometimes professed, how much of them is present as phosphates.

The composition of bones is stated in a different manner, and is given further on.

MATERIALS FOR SUPPLYING NITROGEN IN MANURE.

Besides bones, various other nitrogenous and ammoniacal materials are mixed with phosphates to prepare Nitro-Phosphates and other manures of a similar nature, which supply ammonia in addition to the soluble and insoluble phosphates already spoken of. Again, special manures are prepared from these, or superphosphates simply, in conjunction with sulphate of ammonia, guano, nitrates, potash salts, &c. (see page 116). These materials are either mixed in with the

acid and phosphates during the dissolving process, or, in the latter case, more commonly by the dry process after the superphosphate has been made and brought to a dry condition. This intermixture is effected on the large scale by an ingenious machine called a "Disintegrator," which has also the effect of breaking down all lumps, &c. Almost all manures require to be thus prepared, by this or similar treatment, before being put up in bags for sale, much of the art of the manufacturer consisting in getting his manures in a good condition, and also that they shall remain so until employed in the field.

Bone Dust as source of Nitrogen. — As well known, one of the best forms of nitrogen for manures is that furnished by the organic matter of bones, after having undergone a partial decomposition by acid, as in the recipe already given, and it is to this fact, added to the superiority of the phosphate associated with it, that the preference given by practical men to bone manures when of good quality is to be attributed. In the plan sometimes adopted of mixing the bone dust with the superphosphate after it is made, the nitrogenous matter is much less effective, from the slowness with which it comes into action, and still more so in the case of bone dust employed alone; the use of which indeed, except in peculiar cases, being now considered as almost a waste of bone material.

Assuming bones to contain 4½ per cent. of ammonia (nitrogen equal to), it will require about 8 cwt. in a mixing of 40 cwt. to furnish ·90 per cent. of ammonia in the manure. With the concentration in weight on mixing, before mentioned, and the small quantity of nitrogen always present from other sources, the actual quantity of ammonia in such a mixture, supposing no other source of nitrogen is to be used, will be rather more than 1 per cent. From this example, the amount of nitrogen to be expected from more or less bone will be easily judged of. With reference to the idea sometimes expressed, that bone manures should be made from nothing but bone dust and acid, it may be said that it is not possible to produce such a manure at the price, with the amount of soluble phosphate, and in the condition, now demanded by buyers. Persons who have attempted to make such a manure will at least have learnt the truth of this, so far as regards manures to be offered for sale in the general market.

Ammoniacal Salts—afford the most concentrated sources of ammonia for supplying this element in manures. The sulphate being chiefly employed for this purpose, and is one of the best sources that can be used for concentrated manures, in which a higher proportion of ammonia is needed than can be obtained from bones or other materials.

Sulphate of Ammonia—is now an important article of commerce, most of the "gas liquor" produced in gas

works being now utilized in its preparation. When pure it is white or colourless, and in small crystals resembling sulphate of magnesia or Epsom salts, this material being in fact sometimes used to adulterate it. Sulphate of ammonia occurs of all qualities and colours, the slightly coloured being often the cheapest, since they may contain as much ammonia as the white, though not quite so marketable. Inferior samples sometimes contain sulpho-cyanide, which has an injurious effect on vegetation.

When ordinarily pure, sulphate of ammonia contains as near as possible 25 per cent. or one-fourth its weight of ammonia. The lower qualities contain moisture, free acid, tarry matters, and mineral impurities, chiefly sulphate of iron and sulphate of lime. Since the best sulphate contains 25 per cent. of ammonia, it is clear that 5 cwt. of it, mixed with 15 cwt. of other materials, will yield $6\frac{1}{4}$ per cent. of ammonia in the mixture, and so little as 1 cwt. in 20 will give $1\frac{1}{4}$ per cent. in the mixture. From these examples any other proportion can be easily calculated. Sulphate of ammonia sometimes contains 26 and upwards per cent. of ammonia, due to the presence of chloride of ammonium, and which is unobjectionable.

Chloride or Muriate of Ammonia—is sometimes met with, and contains as much as 36 per cent. when pure. Another salt, the Sulphocyanide, has as much as 41 per cent. of ammonia, but is unfortunately detrimental

to vegetation and cannot be used with safety in manures. It is sometimes used to "bring up" inferior samples of sulphate, and buyers should be on their guard against it.

Patent Ammonia, or Black Ammonia—as sometimes called, is a useful source of ammonia, though sometimes too impure to allow of being safely used in manures. It is the product of the process by which the ammonia is absorbed from gas by passing it through chambers filled with sawdust moistened with sulphuric acid. It often contains 15 or 16 per cent. of ammonia, but more commonly about 10. At the latter strength 2 cwt. in a ton will give 1 per cent. of ammonia in the mixture.

Nitrate of Soda—may here be named as a source of nitrogen, although it will be again referred to as a general manure further on. As a source of nitrogen it is much weaker than sulphate of ammonia, as it contains about 19 per cent. ammonia (nitrogen equal to) in lieu of 25. Supposing the sample to be ordinarily pure, or containing 95 per cent. of real nitrate, 141 lbs. are therefore required to give as much nitrogen as 112 lbs. of sulphate of ammonia. It is not generally known that the nitrogen in nitrates cannot be obtained in the ordinary determination ammonia, but requires a separate operation for its estimation.

Shoddy or Wool Refuse—is a useful and abundant source of nitrogen, containing about 7 to 9 per cent. of

ammonia (nitrogen equal to), and when mixed in with the acid and phosphates in the ordinary dissolving process, undergoes a partial decomposition highly favourable to its assimilation by the plant. This material is the final destination of all woollen fabrics after the fibre has become too short or otherwise unsuitable for respinning. Owing to the bulky nature of shoddy, only a comparatively small quantity can be used for mixing in the ordinary manner; 5 cwt. in a mixing of 40 cwt. of total materials give about 1 per cent. in the product. Larger per centages of ammonia than this can be obtained from shoddy, but require special management.

Wooldust or Flockdust—is a superior kind of shoddy, being in the state of fine dusty powder, and yielding as much as 10 to 12 per cent. of ammonia.

Other materials of similar origin are in use, containing 5 to 6 per cent. of ammonia, and with the above are amongst the cheapest sources of nitrogen.

Blood collected from slaughter-houses is a valuable source of nitrogen, and much used for the preparation of "blood manures;" it contains in its natural state about 3-4 per cent.

Dried Blood—is also employed for the same purpose, though less effective proportionately to the nitrogen present, and is due to a too high temperature being frequently used in its preparation, by which it acquires a leathery character; it contains about 15 per cent. of

ammonia when of best quality. A partially dried blood containing from 6 to 7 per cent of ammonia is a capital material, and is now much used.

Refuse Materials, except those rich in nitrogen, such as flesh and offal, horn, &c. are of but limited application as sources of nitrogen, since they impart too much extraneous matter to allow of the nitrogen reaching any considerable proportion in the mixture; thus a refuse material, containing say 2 per cent. of ammonia, if used at the rate named for shoddy, will yield to the manure only ·25 per cent. Again, such materials often contain oxide of iron, carbonate of lime, and other substances calculated to reduce the soluble phosphate, and so lessen the value of any manurial mixture, so that on the whole such materials are undesirable to use.

Azote Guano,—so called, has been brought from America, and consists of dried flesh in a fine state of division, and yields as much as 13 per cent. of ammonia, and is an excellent source of nitrogen when it can be obtained. Similar materials have appeared from time to time from other sources, and meet with a ready market.

Dried Fish—is now used to a considerable extent, and supplies some valuable manure materials, furnishing about 8 per cent. of ammonia, with about 20 to 30 of bone phosphate of lime. This material is very manageable and cleanly, and might be used directly as manure.

Rape Dust or rape cake, unfit for feeding, is a valuable constituent for manures, as it affords a readily decomposable organic matter, containing 5 to 6 per cent. of ammonia. Other damaged cakes are often obtainable at a moderate cost, and are suitable for use alone or in admixture with superphosphate, &c. as adverted to further on.

Nitrogenous Materials.

	Shoddy No. 1.	Shoddy No. 2.	Wool Dust.	Concentrated Shoddy.	Dried Blood.	Acid Clotted Blood.
Nitrogen, per cent. .	7·90	6·20	9·70	12·40	12·40	5·15
Equal to ammonia .	9·59	7·60	11·98	15·05	15·05	6·25

	Organic Manure. No. 1.	Organic Manure. No. 2.	Rape Cake.	Patent Ammonia.	Sugar Scum.	Damaged Cotton Cake.
Nitrogen, per cent. .	3·3	3·80	4·93	13·40	2·80	5·70
Equal to ammonia .	4·01	4·61	5·98	16·27	3.40	6·92

	Scutch, Glue Refuse.	Fur Waste.	Sud Cake.	Leather Cuttings.	Crude Ammonia.
Nitrogen per cent. . .	2·63	8·50	3·55	8·10	7·70
Equal to ammonia . .	3·20	10·32	4·30	9·83	9·35

Sulphate of Ammonia.

	1.	2.	3.
Moisture	1·24	·93	3·14
*Sulphate of ammonia, with traces of organic matter and other salts of ammonia	98·03	98·57	89·72
Mineral matter	·73	·50	7·14
	100·00	100·00	100·00
*Containing nitrogen . . .	20·02	20·67	15·15
Equal to ammonia	24·30	25·10	18·36

Results of Mixing Process.

Were it not for the remarks sometimes expressed by persons imperfectly acquainted with the subject, it need hardly be said that good manures cannot be made without good materials, and in proportionate quantity; although economy may be practised within certain limits, it is simply impossible to get a high percentage of soluble phosphates without using a good raw phosphate to begin with, and the requisite large quantity of acid.

As regards the weight of superphosphate or other manure produced from a given quantity of materials, this will obviously be equal to the weight of those materials *less* that portion of them volatilized in the mixing process. The extent of this loss varies of course with the materials employed and mode of mixing adopted, but from experiments I made with the view of determining this point, I should consider this loss to average about 7½ per cent. on the total weight of materials used, up to the time of the superphosphates reaching a moderately dry and manageable condition. If, as an illustration, one hundred tons of coprolites are dissolved by an equal weight of chamber acid, we should therefore get, supposing nothing else to be added, about one hundred and eighty-five tons of superphosphate.

In preparing superphosphates from Cambridge coprolites, bone ash, or other materials containing little oxide of iron or alumina, the proportion of total phosphates in the manure can thus be calculated by the rule of simple proportion from the quantities of materials employed, the composition of the latter being of course known. To extend the above examples—if the coprolites had 58 per cent. of phosphate of lime (although this is rather above the present average), we should get 29 per cent. supposing no loss to have occurred in mixing, but taking the loss at the above estimate, we should have the whole of the 58 tons in the 185 tons of superphosphate, or about 31⅓ per cent. In the case of other phosphatic materials, however, a higher percentage of total phosphates is found than could possibly be furnished from the tribasic phosphates in the materials employed, and which may be explained as follows—Such phosphates contain oxide of iron, or less commonly, alumina, which in the ordinary process of analysis is weighed with the undissolved phosphate of lime as a mixture of insoluble phosphates. The separation of these items could of course be further effected, if desired, but is not usually done by chemists, for the reason that it is too lengthy a process to be employed in every case. Moreover, the omission is of little or no consequence, inasmuch as the insoluble phosphates, except when in the form of bone, are often left altogether out of consideration in valuing

a manure (although erroneously as I consider), and also because in a well made manure the insoluble phosphates are too small in quantity (except when from bone) and value to warrant the process of separation above referred to, and which might also lead to confusion.

As regards the relation between the total phosphates in the manure (the phosphate made soluble, and the insoluble together) and the acid used. It is evident that the less acid used, the more total phosphates will be present, but the less of them will be soluble. The converse is also evident: viz., that the more acid used, the less total phosphates, but the more of them will be soluble, but not necessarily the higher percentage in the manure. Thus, supposing we were to use 200 parts of bone ash of 70 per cent. phosphate, and 100 parts of acid we should have in the product 140 parts of phosphate in 300 of material (leaving out for simplicity the loss referred to above), or about 46½ per cent., which is obviously too little acid. If, on the other hand, 100 parts of ash were dissolved with 200 parts of acid, we have only 70 parts of phosphate in the 300 of material, or only about 23⅓ per cent., which is as much too little (the right quantity lying evidently between the two). Although this is of course an extreme case, it is mentioned to prove the fact that beyond a certain point more acid will lessen the percentage of soluble phosphate instead of increasing it—

simply because it brings down the total phosphates too low, notwithstanding the whole of this (as far as practicable) may be made soluble.

Again, the addition of any extra quantity of water in mixing of course lowers the percentage of everything in the manure: many makers take no account of the weight of water used (the better plan is to use a weaker acid and no water); and, when left to the men engaged in the operation, is the commonest source of variation in the product—especially as a little extra water gets the work on quicker. If a bone manure, when freshly made, is found to contain—say 25 per cent. of soluble, but does not dry up well, and it is thought advisable to add a little drying material, the mass will not have 25 per cent. after the addition of such material, since the same quantity of phosphate is spread over the increased quantity of material. Although this may appear self-evident to some, it would seem to be incomprehensible to others, to judge by the correspondence I sometimes receive.

As regards the soluble phosphate produced from a given weight of acid — the theoretical quantity is 80 parts of real acid (SO_3) for 155 parts of tribasic phosphate; or for 100 parts of bone ash, as above, $55\frac{1}{2}$ parts of ordinary brown acid.

Bone ash, however, also contains, as well known, variable quantities of carbonate of lime as well as phosphate,—while other phosphatic materials often

contain much more carbonate, and also oxide of iron, alumina, &c.; but, taking all these into account, it is found, as well known, in practice, that more than the theoretical quantity of acid is always needed, and which may I think be due to the following causes:—

(A.) To the necessarily imperfect state of division of the phosphatic materials operated on, even when ground as fine as practically possible, and by which a portion of the phosphate of lime escapes actual contact with the acid, even under the best mechanical arrangements. This is shown by the fact that the finer the state of division the more complete the decomposition,—it being almost instantaneous in the case of chemically divided phosphate. A too rapid decomposition is not, however, the most desirable in practice: hence the necessary excess of acid is borne with for practical considerations presently to be touched on.

(B.) To acid consumed in decomposing phosphates which are not rendered actually soluble, and on which the question of precipitated phosphates I think throws some light. This is especially noticeable in well-made bone manures in which the greater part and sometimes the whole of the bone has evidently undergone decomposition, as proved by its mellow and pulverulent condition, although only a portion of it is obtained as actual soluble phosphate on analysis.

The same rules of proportion of course apply to

any other materials which may be added in making superphosphate, or mixed together in the preparation of special manures, and are often of much practical value, although not so much regarded as they should be.

Recipe for Home-made Bone Manure.

If any farmer should wish to try his hand at dissolving bones, the following recipe may be followed—the product being of course only intended for use on the spot:—

For a ton of bones, which should be ground small and boiled to extract as much as possible of the fat, the following quantities of acid and water may be used, viz., 740 lbs. white oil of vitriol, or 850 lbs. brown acid; this is about equivalent to 41 gallons of the former and 50 gallons of the latter.

1000 lbs., or about 100 gallons of water, are divided equally, one part being used to moisten the bones and the other to dilute the acid. The latter operation should be carefully performed in a large bucket or tub—pouring the acid in a small stream into the water—the latter being well stirred meanwhile. The bones should be thoroughly moistened with water from a garden watering-can, and left for two or three hours, or longer, to get well soaked. The mixing should be made in a wooden trough or large tub; if a sufficiently large vessel cannot be had to receive all the

materials at once, it may be done in a smaller one, using successive and proportionate quantities of bones and acid; or the mixture may be made, but not so well, on the ground (with a hard clay surface if possible), a ring being made with ashes (black or red, about equal in weight to the water used) to prevent the liquid flowing away. The acid should be gradually added to the bones, the whole being well stirred with a wooden rake to ensure uniform admixture. As soon as the acid is all added and the mixing completed, the greater part of the ashes may be thrown over the mass, and the whole allowed to stand for some days. The heap may then be opened, and the whole of the ashes well incorporated with it; the mass being then allowed to stand again for a week or so, and if not then sufficiently dry may be broken up again and re-made into a heap, with thin layers of fresh dry ashes. By this means a manure may be got perfectly dry and manageable—the large addition of ashes being, of course, no great objection when, as we are supposing, it is to be consumed on the farm where made.

A manure made in this way, with the first quantity of ashes mentioned, was found to contain 12·27 per cent. of soluble phosphate, and nitrogen equal to 2·07 of ammonia.

CHAPTER III.

BUYING MANURES.

THE next point for our consideration is whether to make or buy the superphosphates or other mixed manures we require, this being of course, when the quantity is large, a matter worthy of consideration, especially in the case of those who, although not regular dealers, are in the habit of supplying a few neighbours as well as themselves.

In favour of making it has been said—1st, that you save the maker's and agent's profit. 2nd, that you get the labour for little or nothing, by having it done at times when the men would be otherwise unprofitably occupied. 3rd, that you know what is put into your manures, and so ensure freedom from adulteration. On the other hand, it may be said that it is impossible to make to the same advantage on the small scale, with extemporized apparatus as in properly arranged works, and that the profits of the manufacturer and his agents are derived from sources not at the command of the consumer or small dealer—such as the purchase of materials in large quantities by means of capital specially devoted to the purpose (without which he cannot

succeed), the manufacture of acid, and the application of steam-power to almost every operation that would have to be done on the small scale by hand. Another drawback to making is the high rate charged by the railway companies for the carriage of acid, which they consider a dangerous article; this is perhaps the most serious bar to making manures, except in localities where it can be otherwise obtained.

As regards genuineness, we must not forget that the raw phosphates are as likely to be adulterated, or supplied of low quality, as manufactured manures—in fact a common source of inferiority in the latter is the still too common practice of manufacturers accepting unquestioned the quality of the raw materials they are supplied with. Analysis by competent chemists is the only guide in the purchase of all such articles, and to omit this precaution, to save the cost of analysis, is very false economy.

The strongest argument however against the making of manures is the fact within my knowledge, of more than one large farmer, who at first impressed with the advantages of making for himself, set to work in earnest to do so, and succeeded to his entire satisfaction—in fact has made manures fully equal in every respect to the best in the market (which is more than every amateur can say), and has yet since given up the practice, through finding he can buy cheaper.

Every one will however be able to judge for himself

on this point, by calculating the cost of materials from the advertized price-lists for the quantities given in the foregoing recipes, with the cost of carriage for acid, &c., to his own place.

Mineral Superphosphates.

What kind of superphosphate to buy will of course depend on the use to which we intend to put it. When used in conjunction with farmyard dung a mineral superphosphate is often sufficient—in fact without dung, but used freely, this kind of manure suffices on many soils to yield good root crops, although I do not recommend the practice. For using also in conjunction with guano, as a corn manure, this kind of superphosphate is admirably adapted, as adverted to under "Using manures." Mineral superphosphates owe their value almost entirely to the soluble phosphate they contain.

In speaking of soluble phosphate, it may be premised that all buyers and sellers are now well aware that the various mineral phosphates are a perfectly legitimate source of this constituent of manures, and which so derived is in every respect as good as that obtained from bone. In the case of actual bone, the undissolved portion is of course as valuable, or, as I have always held, considerably more so than ordinary crushed bone, in consequence of the semi-dissolving process it has undergone. On the other hand, that

left undissolved from the use of bone ash or mineral phosphates is, at least so far as all present action is concerned, useless, and should consequently be avoided as far as possible, although I do not go the length of saying, as held by some, that it is positively worthless, and for the following reason. In all alluvial soils of natural fertility we find the phosphoric acid in the insoluble form, and chiefly in the form of phosphate of iron or alumina—these bases having the power of decomposing any other phosphates originally present. The same thing must occur when phosphatic manures are applied to ordinary soils, in which hydrated oxide of iron and alumina abound.

Mineral superphosphates are made of all qualities—from 20 and under up to 40 and even much higher. The higher qualities are more suitable for special purposes, as, for instance, exportation to the Colonies, where a high freight or long inland transport renders any reduction of weight of importance, rather than for ordinary use in the field. High class superphosphates are, however, sometimes cheaper than the lower ones if care be taken to employ them properly; that is, in proportionately lower quantity per acre. One having 40 per cent. is of course twice as valuable as another having 20 per cent., and if used in half the quantity of the latter, would have an equally good effect provided all necessary care be taken in its application. This, although self-evident, is often

lost sight of in the employment of concentrated manures.

Ordinary mineral superphosphates should have at least 25 per cent. soluble phosphates (phosphate of lime made soluble), although many reach 26, 27, 28, and even 30 and over per cent. Differences of this extent we frequently found in samples of one price— the higher qualities of course depending entirely on price.

In mineral superphosphate of whatever quality the soluble phosphate is therefore the chief item of value, hence it is of course very necessary to know with certainty at least the proportion of this constituent present. This should be ascertained by having a sample from the bulk delivered, tested by a competent chemist, as however honestly we may be served, the intended percentage of soluble phosphate cannot always be ensured for various reasons which need not here be entered upon.

Bone Superphosphates and Bone Manures.

These are of course superior to the above, but of higher price, the bone left undissolved in them furnishes a more lasting supply of insoluble phosphate which comes in during the later stages of the growth of the crop, and which at the same time supplies nitrogenized organic matter. It is not to be supposed that this kind of super-

phosphate is made entirely from bones—such a manure being now rarely met with, but from bone in conjunction with either bone ash or minerals. For the insoluble phosphates fresh bone only should be used, as bone ash, unless made soluble, is but little, if at all, better than mineral phosphate, as I have proved by recent experiments, and a high percentage of it in a manure is of no better value than the same quantity of mineral phosphate.

Bone ash, as already mentioned, dissolves easier than any other phosphatic material, it being possible to make from it very high qualities of superphosphate, containing 40 or more per cent. of soluble phosphate. It is thus a positive waste to put it in the soil undissolved, as often met with in manures under the erroneous idea that being bone material it is but little inferior to bone itself. A good bone superphosphate is given at No. 2 in the subjoined table.

Under the name of Dissolved Bones there are at present some very superior manures to be had, having a high percentage of soluble phosphate with a good deal of bone in a well softened state, and yielding besides insoluble phosphates of the best description, a good deal of nitrogen, which materially assists the action of the phosphates.

A manure of this kind, when it can be had for a reasonable price, is, I consider, one of the cheapest and best forms in which we can expend our money, as it

supplies all the elements of vegetable nutrition in a matured and highly beneficial form.

It may here be mentioned that bone manures, and other kinds to a less extent, often lose on keeping some of the soluble phosphate they at first contained, and which now appears as reduced or precipitated phosphates. This is because the soluble phosphate is a very unstable compound, always exhibiting an inclination, so to speak, to get back to its original condition. Not only alkaline substances like the soda we used in our experiment (page 14), but neutral compounds like oxide of iron, organic matter, carbonate of lime, or even insoluble phosphate of lime, have this effect in a slower degree, and render it again insoluble. Even heating no higher than boiling water is, under certain circumstances, sufficient to cause its precipitation: hence an error frequently made in the analysis of such manures, in which cold water only should be used for extracting the soluble phosphate.

In a freshly made bone manure the undissolved bone is for the greater part unaltered, or merely softened more or less on the surface; in a more matured sample, however, we find the bone, although perhaps retaining its original shape and structure, is soft and crumbly, and has evidently undergone a further decomposition, and is thereby greatly improved as a fertilizing agent. It is found that this change is at the expense of some of the soluble phosphate,

which has now passed into the above-named condition. This circumstance deters many manufacturers from trying to produce a really first-class dissolved bone (than which no better manure for general use is to be had), since they find that some analysts give them no adequate value for such a product. (See Valuation of Manure.)

The composition of the manures now under notice is shown in the following table:—

	No. 1.	No. 2.	No. 3.	No. 4.
Moisture	12·16	18·40	15·11	17·22
*Organic matter, &c.	17·04	14·34	20·21	11·22
Biphosphate of lime	14·12	15·43	13·34	17·15
Equal to bone-earth made soluble	(22·04)	(24·13)	(20·82)	(26·76)
Insoluble phosphates	14·79	8·40	6·56	5·13
Sulphate of lime	32·12	35·29	36·36	40·28
Alkaline salts	4·67	2·50	2·29	3·04
Insoluble matters	5·10	5·34	6·14	5·96
	100·00	100·00	100·00	100·00
*Containing nitrogen	1·40	·74	1·01	Traces
Equal to ammonia	1·70	·90	1·21	...

No. 1 is a dissolved Bone of superior quality—the best samples averaging 20 to 24 per cent. soluble phosphate, with 9 to 12 of insoluble, and 1½ to 1¾ of ammonia. In this sample the precipitated phosphate was determined, and found to be 3·43 per cent. No. 2 is a bone manure of lower quality, although higher than No. 1 in soluble phosphate, but the bone

is much less, the ammonia being little more than half the percentage of No. 1. No. 3 is a nitro-phosphate of fair quality. No. 4 is a mineral superphosphate of good quality.

Chemists adopt somewhat different modes of stating their results, but in all cases the more essential constituents are the soluble phosphate, the insoluble ditto, and the nitrogen equal to ammonia. The other constituents are of smaller importance, except when nitrates are present, when they appear amongst the alkaline salts, and the nitrogen of which should be added to that from organic matter, &c. Potash also when present occurs in the alkaline salts.

The soluble phosphate always means the tribasic phosphate *made soluble by acid,* whether it be stated as biphosphate, monobasic phosphate, or soluble phosphoric acid. I see no advantage in stating the soluble and insoluble phosphoric acid, as adopted in some analyses, as the latter is of quite as indefinite value in manufactured manures as insoluble phosphates, and depends entirely for its value on the form in which it exists, whether as bone, guano phosphate, precipitated phosphate, undissolved coprolite, or what not; and, moreover, there is a greater liability to error in the determination of phosphoric acid, which requires special care and longer time.

Explanation of Constituents of Manures as shown by Analysis.

As it is very desirable that buyers and others should clearly understand the wording, and meaning of an analysis, the following explanation of the more commonly occurring constituents, it is hoped will prove of service. The items are taken in the order usually adopted, and as stated in the foregoing table.

Moisture—is the water unavoidably present with the acid employed; or added, if the strong acid is used as in the foregoing recipes. A considerable proportion of this is again lost by drying when the manure is kept any length of time.

The question of moisture is often one of some importance to practical men, since it influences by the rule of proportion before referred to, the proportions of other constituents on which the value of the manure depends. Thus as a quantity of manure dries, it of course loses in total weight: if a hundred tons, say, to begin with, and it only loses 5 per cent. there will now be only 95 tons. The 7½ per cent. mentioned as loss in making superphosphates it will be remembered is the amount lost up to the time of its gaining a good manageable condition, which should be in a week or two after making,—but if kept for two or three months longer, the loss will be considerably greater than this.

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In the case of raw phosphates also the difference arising from this cause, that is the extent to which the moisture influences the percentage of phosphate of lime, is often striking, and might almost at times be doubted, were it not a matter of hard fact and figures, which any one as well as a chemist can calculate. Thus, a sample which in dry state gives say 70 per cent. phosphate of lime, will if calculated for the natural condition, with say 10 per cent. of moisture (round numbers only being taken for simplicity) give only 63 per cent.

Again, supposing the sample analysed contained 2 per cent. moisture instead of being quite dry, the result in this case would be 68·6 instead of 70, and if calculated for 10 per cent. moisture would of course give 63 per cent. for the natural state—showing that it makes no difference whether the dried portion is completely dry or not. On the other hand, if the dried sample containing 2 per cent. moisture were assumed to be dry, and so calculated, we should get 61·74 per cent. instead of 63. This might arise from a finely ground and perfectly dry sample being exposed for some time to the air, from which it would absorb moisture though rarely to the extent of 2 per cent.

In the case of a sample incompletely dried and afterwards analysed, a slightly different calculation is needed. Thus, suppose a quantity (say of the above sample) is dried and found to lose 8 per cent. moisture,

and is afterwards found to have still 2 per cent. moisture. The latter would of course have as before 68·6 per cent. phosphate, and calculated for the natural state would have again 63 per cent. and not 64·4 as we might be misled into supposing if calculated in the same manner as the foregoing example.

Organic Matter—is the general term applied by chemists to all substances of animal or vegetable origin which are decomposed by heating or subject to decay. Thus hair, wool, cotton, sawdust, &c. are all organic matters although they possess very different manurial values. This is found to depend almost entirely on the amount of nitrogen they contain, or in other words, on the amount of ammonia they are capable of yielding by decomposition. Thus hair, wool, horn, and most kinds of animal matter (except fat) contain much nitrogen and are valuable as manure; while cotton, saw-dust, bark, &c. have only traces of nitrogen and are almost worthless as manure. Thus we perceive the reason for stating this item in the manner shown in the table, viz., organic matter, &c. containing nitrogen, equal to ammonia. The total amount of organic matter or other bodies occurring under this item, is of little consequence, because it may be non-nitrogenous; but the further direct estimation of the nitrogen, from which the ammonia is calculated, at once shows what kind of organic matter it is, and its manurial value. Associated with this item in an

analysis, one often meets with, the term "ammoniacal salts" and also "water of combination."

Ammonia is an invisible gas like atmospheric air. but possesses a strong pungent odour familiar to all as given off from smelling salts. If we mix a little guano or sulphate of ammonia with lime and sufficient water to make a stiff paste, on stirring the mass we shall liberate large quantities of ammonia which although invisible, is soon made manifest through our nose. This is ammonia gas, which under these circumstances is set free from the ammoniacal salts occurring in either of these materials, and which contain the ammonia combined with an acid in a fixed or non-volatile state. What is called "fixed" ammonia is ammonia in this state of combination in which it no longer exhibits its pungent smell, and is incapable of flying off except at a high temperature. The value of all such salts as manure, depends on the same rule as for organic matter, viz., the amount of actual ammonia they yield. (See under.)

Water of combination is a useless though unavoidable constituent of all superphosphates, being the water chemically combined with the sulphate of lime or gypsum, formed by the action of the sulphuric acid upon the lime occurring in the various phosphates employed, as before mentioned.

Nitrogen, equal to Ammonia.—Lastly, under the analysis, we always find this item which, as above

explained, expresses the actual quality of the manure in respect to the organic matter or ammoniacal salts it contains. It may be added that one per cent. of ammonia is equal to about four per cent. of sulphate of ammonia. This leads me to remark that the usual mode of stating the amount of ammonia in manures, as above, is hardly so good or fair as could be wished, since the amount of ammonia stated is the ammonia gas before mentioned, and is the lowest possible shape in which it is possible to express it, and is moreover an artificial condition in which it never occurs in nature. Even free ammonia, so-called, as it occurs in nature, is in reality carbonate of ammonia, and would have a much higher figure. As sulphate of ammonia is, however, best known, and is a tangible salt well known in commerce, it conveys a much better idea of the quantity of ammonia present. I therefore frequently state the ammonia in analysis as equal to pure sulphate of ammonia, as well as in the ordinary way, and shall be always ready to do so when requested. It need hardly be said that this or any other mode of stating the result in no way affects the proportion of ammonia present, which is calculated from the direct estimation of nitrogen, and includes the nitrogen present both in salts of ammonia and organic matter, as before described.

When nitrate of soda is present, it occurs under the item alkaline salts; and the nitrogen in which should be added to that as above (since it cannot be obtained

in the same manner), and the whole calculated as ammonia.

BIPHOSPHATE OF LIME, EQUAL TO BONE-EARTH MADE SOLUBLE. This item has already been referred to as one of the primary constituents in all manures of the kind now under consideration, its value in the soil depending, as well known, on its ability to supply the plant with the phosphatic food so largely required in the development of roots, grain, and in fact all kinds of agricultural produce.

We have already mentioned biphosphate of lime as the product resulting from the action of the sulphuric acid on the natural or tribasic phosphate of lime or bone-earth. What is commonly understood by soluble phosphate is the bone-earth so decomposed—not the biphosphate—although it is in this latter form that it exists in the manure; hence the reason for stating this item as above. When we say 25 per cent. soluble phosphate, we therefore mean 25 per cent. of phosphate made soluble (often so stated when a complete analysis is not required), and not 25 per cent. of biphosphate: this latter would be about 16 per cent., and is calculated from the former when the complete analysis is given, for the reason above stated.

PHOSPHORIC ACID, SOLUBLE IN WATER.—Superphosphates are now often analysed by determining directly the phosphoric acid soluble in water, and which is supposed to give a more definite expression of their

composition and value. The plan, however, cannot be recommended for general use, since it has the drawback of increased liability to error, consequent on the delicacy of the process for determining phosphoric acid by whichever method adopted. Also in point of time, any curtailment of which leads to an inaccurate result. This method is, however, preferred by Continental buyers, and can always be adopted when desired.

PRECIPITATED OR REDUCED PHOSPHATE may be regarded as holding an intermediate place between soluble and insoluble phosphate, and although some chemists do not separately identify it from the latter, its occurrence, sometimes in large proportion, is well known to all who have anything to do with the analysis of superphosphates. (See page 46).

INSOLUBLE PHOSPHATES.—As it is impossible in practice to render the whole of the phosphate of lime soluble, even if it were wished to do so, there is always found in superphosphates more or less insoluble phosphates or phosphate of lime in its original unchanged state. In superphosphates made from minerals this item is often considered of little or no value, for the reason that it is unassimilable by plants, but it may be doubted whether in the long run it does not slowly become available, seeing that the natural phosphates of the soil are present in similar combinations. When bones are used, as in the recipes before given, the insoluble phosphate will consist of bone more or

less changed by the acid employed, and constitutes an item of considerable value. Many of the phosphatic guanos furnish superior insoluble phosphates. Also the various kinds of bone-meal, steamed bones, &c.

SULPHATE OF LIME, also called gypsum, occurs in large quantity in all superphosphates, being, as above mentioned, the result of the acid acting on the phosphate and carbonate of lime present in the raw phosphates employed. A little is also added in some cases to assist in drying the manure. This property of sulphate of lime to take up water chemically is one of much value in connection with superphosphates, as it is the cause of their drying up spontaneously and passing into the state of powder so necessary to their effective employment as manures. Sulphate of lime also has a low but decided value as manure, and on soils deficient in sulphates is often highly beneficial. In buying superphosphates we get this substance into the bargain, although it is often separately purchased, especially for application to grass land. The burned, or rather baked gypsum is most effective for drying purposes, and takes up about one-fourth its weight of water to form water of combination which does not dry off like moisture. This baked gypsum is the well known article called plaster of Paris. Gypsum often contains carbonate of lime, and is then unfit for drying purposes, as it "kills" the acid and undoes what we have been doing by the dissolving process.

Alkaline Salts consist mostly of sulphate of soda derived from the common salt accidentally present in the materials employed, and sometimes added, with smaller quantities of potash derived from the same source. When salts of potash are added in mixed manures, they come under this item, and have a special value. Potash is now much used in this manner, being found to have a good effect in conjunction with phosphates. Nitrates also occur here as before explained.

Insoluble silicious matters consist of the earthy or sandy matter naturally present more or less in all the phosphates, and is to be considered an unavoidable though useless item. In adulterated or very inferior manures, however, this item will include any earthy matter which may have been added, as in the examples given under adulterated manures, and in such cases often forms the largest item in the analysis.

The table of analyses given at p. 47, will illustrate the foregoing remarks, and show about in what proportions the several items mentioned occur in good samples. As I sometimes meet with persons who have forgotten their decimals, and to whom the decimal mode of stating the analysis is the most puzzling thing about it, I may add for their benefit, that the figures simply represent the proportions by weight in 100 parts, whether ounces, pounds, or tons, and could not well be shown in any other way. For instance, 25 per

cent. of soluble phosphates might be expressed by saying that the manure contains one quarter or one-fourth part of soluble phosphates, and if it had 33 per cent. we might say it had about one-third, but if as generally happens, the proportion is some irregular quantity, such as 23, 27, 30, or what not, these vulgar fractions would no longer express what is required, but which is at a glance shown by the decimals in the 100 parts.

It may be added that for practical purposes the figures on the right-hand side of the point or dot may be disregarded, except in the case of ammonia; although it is better to bear in mind, and in the case of ammonia, essential to do so, that ·50 is one half a per cent., ·25 one quarter, and ·75 three-quarters of one unit, or one-hundredth part. One per cent., or a hundredth part, is a considerable quantity of ammonia, hence it is important to know whether there be 1, 2, 3, or more tenths over or under the quantity bargained for, and this is what is represented by the figures on the right-hand side of the point, the one unit, or 1 per cent., being there divided again into 100 parts, as will be seen by any one after a little consideration.

Nitro-Phosphates, Night-Soil Phosphates, etc.

We have next to mention nitro-phosphates, by which is usually understood a superphosphate in which the

organic matter of the bone is replaced by some other nitrogenous organic matter, such as blood, wool refuse, &c.: these manures, when of good quality, have an excellent effect in the soil, the effect of the acid on the organic matter being to bring it into a state of incipient decomposition highly favourable to assimilation by plants; hence we find that the same kind of organic matter so treated acts more efficiently than in its natural state.

Another kind of phosphatic manure should also be noticed, viz., "night-soil phosphates," which promise ere long to assist in solving the sewage difficulty. In the best of these patents, the solid and liquid excrements, *without the addition of water*, are treated with acid and phosphatic materials, as in making superphosphate, the result being a manure combining the well-known fertilizing properties of night-soil with those of superphosphate. Some of these manures that have come under my notice have been of very fair quality, although from various practical difficulties connected with the manufacture, they do not of late appear to be much used.

The majority of the manures obtained by precipitation in the purification of sewage, are of very poor quality, chiefly from the paucity of nitrogen, which cannot be precipitated by any known process. It is unnecessary to give the analyses of these articles, which consist generally of silicious matter, organic matter

with very little nitrogen, a little phosphate, and the materials used for precipitation. The following passage from a recent report of mine may here be quoted.

"At the same time there is still in many districts a great want of knowledge on the subject of vegetable nutrition and what constitutes money's-worth in the shape of artificial manure. An instance of this is afforded by the efforts made in several localities, in some cases at a large outlay, to prepare a so-called manure from sewage by precipitation. Town authorities are of course anxious to get rid of their sewage, and when led to believe they can do so at a profit by such processes, have been induced to enter upon schemes altogether wanting in sound principles. To the credit of farmers, however, the sale of such products does not appear to have met with the success anticipated by the promoters. It may be accepted as a chemical impossibility ever to prepare, *by precipitation* from sewage, a manure which shall repay its cost of production when its true commercial value is found either by practical experience or trustworthy analysis. There is no question of the manurial value of human excrements, and it is quite possible to prepare from them a valuable artificial manure, *but this must be done before it has been mixed with water*, since, when this has once been done, owing to the solubility of the valuable constituents, and to the fact that there is no practical means of precipitating them again, such

matter is practically worthless, except for irrigation; for which purpose, however, it is in my opinion, far too little prized. I have been led to make these remarks from the great importance of the subject, and in order that consumers of manure should have some idea of the nature of the above preparations."

In connection with this subject I may just refer to one popular error which goes far to subvert even the partial utilization as manure, of human excreta. It is that the solid portion is the valuable portion, while the liquid is useless; the same applies also to the manure produced in farmsteads. This error, founded on the general impressions conveyed by our unaided senses, is no more than natural, but none the less mischievous, and ought to have been long since dispelled by the teaching of science, not only on economic, but on sanitary grounds. So far from this impression being true, the contrary is the fact, since the urine contains almost the whole of the nitrogenous compounds contained in the food, *but in a soluble form.* It is in this shape that the thousands of tons of valuable fertilizing matter is allowed to be irrevocably lost in the sea, which might be saved if kept out of the sewers; while at the same time it is the chief source of the unwholesomeness and repulsiveness of some drinking waters; as there are no known means of removing it again when once added to a stream or well. It is difficult for persons unacquainted with chemistry, and even

for some who are, properly to realize the property of solubility and its bearings on natural processes, or in other words, to see that a clear and often colourless liquid can be loaded with solid matter in an invisible form. It is this which gives rise to the popular impression that urine can be of little worth compared with the solid excrement, either of man or beast, and hence even in the attempt to utilize the former, a grievous mistake is often made, as in the case of the French Poudrettes; while in the latter, there will always be a serious deficit of nitrogen on the farm, unless the floors of stables, &c., are provided to save the liquid as well as solid excrements of the horses and other animals; while for the same reason, any well at all within reach (the distance depending on the character of the soil) will become contaminated.

Manures prepared from urine have been submitted to me for analysis, and have proved almost equal to guano, and which is no more than reasonable, seeing that it contains in its natural state about 1¼ per cent. of ammonia (nitrogen equal to), while the solid dry residue obtained by its evaporation is one of the richest nitrogenous materials known, containing not only a very high percentage of ammonia, but also a large proportion of phosphoric acid, with which part of the ammonia is combined, thus forming one of the richest possible manurial combinations. Yet here is this liquid, which might be obtained in any quantity, allowed to waste or

worse than waste, since if it were withheld from the sewers half the difficulty of dealing with their contents would be removed.

As the collection of this liquid from factories, public urinals, &c., is not attended with the same difficulties which appear to form such a serious obstacle to the house-to-house collection of the contents of closets, there appears no reason why it should not be utilized by evaporation in closed vessels, in a similar manner to the preparation of sulphate of ammonia from gas liquor. It is true there is a slight difficulty in the way of drying up the residue, which is of a peculiarly deliquescent or undriable character, hence the use of an absorbent might be necessary, but from the richness of the material in nitrogen as above pointed out this might be used without reducing the product below a marketable quality. It may be added that one of the best absorbents is the solid excrement dried up with the urine, hence the collection of the two and drying up in this manner would appear to be the natural and reasonable disposal of them, although at present apparently attended with insuperable difficulties. These remarks as to details, although perhaps rather out of place, are offered merely as hints as to how it is to be done; there are doubtless practical difficulties to be overcome, or it would have been done long since, but the subject is well worthy of practical experiment, both as a source of profit, as well as towards removing

the reproach to our so-called advanced science, which appears powerless to avert this wholesale drain of fertilizing elements from the land, which should be a source of profit instead of disease as at present.

It must be distinctly understood that these remarks do not apply to *sewage*, the treatment of which by any such plan is of course wholly inadmissible, from the dilution by water which all valuable constituents have undergone.

CHAPTER IV.

BONE DUST, GUANO, NITRATE, ETC.

THE following articles must needs be bought, being natural products, although so-called artificial manures.

BONES are an old and favourite artificial manure, their striking effects in some cases on grass land having done much towards stimulating inquiry into the first principles of agricultural chemistry in years past. At present bones are mainly employed by manufacturers for dissolving in conjunction with other materials in the preparation of bone manures, although, as just referred to, a considerable quantity are still employed in their unaltered crushed state. Except for special purposes, however, such as for use on sandy soils or for certain kinds of grass land, the employment in this way cannot be recommended, since a better effect in every respect can be obtained at less cost by the use of other materials, notably soluble phosphates, mixed with the bones, in place of all bones.

In bones the nitrogen and phosphate of lime are dor-

mant, so to speak, or require a long time for their becoming active plant food on the majority of soils. Hence, although bones have a special value of their own, for all present purposes they cannot be compared in their raw state with other manures of the same strength, or rather having the same proportions of nitrogen and phosphates, in an active condition.

No. 1 in the following table represents a good sample of pure crushed bones: this is rather above the average percentage of nitrogen, this sample being especially dry and clean, that is free from dirt or sandy matter. No. 3 is steamed bones, in which a portion of the gelatine or nitrogenous matter of the bone is extracted. In all cases it is advisable to use bones from which the fat has been extracted, since fat is not only valueless in the soil, but retards the decay of the bone; in fact, it is the fat deposited throughout the structure of the bone, coupled with its hard structure, which renders it so slow of action as a manure.

A kind of bone is occasionally met with in commerce termed Egyptian bones, in which the greater part of the gelatine appears to have decayed, leaving the bone in a brittle and dusty state, and in which the nitrogen is consequently very low, as shown in No. 6. Similar samples are also obtained when gelatine is manufactured from bones by the agency of steam, of which No. 4 is an example from France.

A very beautiful bone material of recent introduction is shown in No. 2: it is prepared from pure bones with animal matter (of easy decomposition) in an almost impalpable powder. Another sample of higher quality is shown in No. 7.

The dried fish shown at No. 5, and before referred to, is a useful constituent of manure, being rich in nitrogen and phosphate of lime, and in a good dry condition. The phosphate is often lower than in this example.

Several kinds of bone meal of various qualities are now in the market, and when of good quality are superior to ordinary bone dust, since many of them contain dried animal matter in addition to the bone.

BONE MATERIALS.

	1. Crushed Bone.	2. Fine Bone Meal.	3. Steamed Bone.	4. French Bone Meal.	5. Dried Fish.	6. Egyptian Bone.	7. Meat Meal.
Moisture	7·13	5·82	7·40	5·20	...	...	8·10
*Nitrogenized organic matter	36·61	41·13	31·69	17·50	...	...	50·66
Phosphate of lime	48·32	45·22	52·11	67·53	30·40	58·31	33·64
Carbonate of lime, etc.	7·11	6·00	7·19	9·31	...	...	6·45
Insoluble matter	·83	1·83	1·61	·46	...	...	1·15
	100·00	100·00	100·00	100·00			100·00
*Containing nitrogen	3·75	4·60	3·13	1·60	7·20	1·57	6·88
Equal to ammonia	4·56	5·58	3·80	1·94	8·74	1·90	8·30

Peruvian Guano, etc.

Peruvian guano, although fallen off considerably from what it was some years since, is still one of the great standard manures, and likely to remain so for the present at least.

The original deposits on the Chincha Islands have been, as is well known, exhausted for some time, and the inferior deposits now drawn upon are unfortunately not only of generally lower quality, but also of very uncertain composition. Thus, while Peruvian guano formerly contained 16 to 18 per cent. of ammonia, and was so uniform in composition that no analysis was necessary when it was known to be genuine, the best now contains 11 to 12, the majority 9 to 11, while many are much lower, and hence an analysis is in all cases necessary even of genuine samples. Greater care has however been taken of late in shipping cargoes, so that it is on the whole better than the guano imported two or three years since. Moreover, as the Peruvian Government has now adopted the more reasonable course of allowing the guano to be sold at prices according to its quality, the grievance that until lately existed of having to pay one price for guano, which was known to differ in money value in different samples as much as £3., £4., and £5. per ton, is now removed, and hence this valuable manure, which was beginning to lose the confidence of farmers through

the exorbitant price of the lower samples, and the constant disputes arising therefrom between buyers and sellers, is now regaining favour.

The subjoined analyses are selected as good examples from a great many I have analysed this year: No. 1 is a superior sample, No. 2 a good sample, and Nos. 3 and 4 of low quality, although rich in phosphates. Although of inferior quality, these latter are genuine, that is, intheir natural state. An imperfect appreciation of this fact often leads farmers to become victims to unscrupulous dealers.

The condition of samples of guano has been much better of late. The damp samples were the rule some time since, and which are difficult to prepare for the field—the lumps becoming pasty on beating, and not easily sifting. For the same reason there is a greater loss of ammonia from such samples, as evidenced by their strong ammoniacal odour.

The clay-like lumps found in Peruvian guano, and which I know some farmers regard as really clay, or something akin to it, are in fact the richest portion of it, and should be carefully preserved when putting the guano through a sieve or screen. They should be chopped down with a shovel or spade with dry ashes or gypsum if it can be had, as from their extreme richness in ammoniacal salts, they may do injury if applied to the crop in the crude state.

The occurrence of these lumps in Peruvian guano,

and its consequent damp condition, necessitate greater care in its analysis than when dry, much trouble and labour being requisite to rub down the sample, after careful chopping, to a uniform paste, without which the actual percentage of ammonia in the sample cannot be accurately ascertained. The following table represents the composition of Peruvian guano, stated in the form officially adopted.

COMPOSITION OF PERUVIAN GUANO.

	1.	2.	3.	4.
Moisture	11·14	14·13	18·36	15·13
*Organic matter and salts of ammonia . . .	45·24	38·24	19·93	14·50
Phosphate of lime . .	26·12	25·13	36·32	32·16
†Alkaline salts . . .	12·00	16·97	12·32	9·08
Insoluble silicious matter	5·50	5·53	14·17	29·13
	100·00	100·00	100·00	100·00
*Containing nitrogen .	9·50	8·40	3·50	2·60
Equal to ammonia . .	11·53	10·20	4·25	3·18
†Containing phosphoric acid	1·19	1·61	1·20	Traces
Equal to tribasic phosphate of lime . . .	2·60	3·52	2·62	
Total phosphoric acid .	13·17	15·03	19·25	

The unshaken belief in guano entertained by some farmers may be explained by the fact that in many cases they get as good a crop from it now as they did formerly, and this leads them to think that analysis may after all be at fault. The fact is, however, that in the majority of cases, 8 to 10 per cent. of ammonia is

quite sufficient to apply in any manure at the ordinary rate, and the larger quantity formerly used was in too many instances wasted. This circumstance has also covered a multitude of sins in the way of adulterated guanos: the farmer may have used a guano adulterated one-half or perhaps two-thirds, but as it still gave him a good crop if the season proved favourable, he was satisfied, and nothing said.

Dissolved Peruvian guano is now well established in the English market, and merits special attention from its high quality as a manure, and the advantages it offers in the way of uniform guaranteed composition, and good marketable condition. These merits I have found fully borne out in my analyses of it, and which I have pointed out at greater length in my official report of it to the manufacturers, with which most agriculturists are doubtless familiar. Its composition is given at No. 1 in the following table, although this example is above the present guarantee. The use of this article would doubtless be more extended were its price the same as the unaltered guano.

The following table represents the composition of some of the principal high-class manufactured manures offered as substitutes for guano, and will no doubt be recognized from the published reports I have supplied to their several manufacturers as to their merits.

CONCENTRATED MANURES.

	1.	2.	3.	4.	5.
Moisture . . .	11·30	8·13	93·09	14·13	14·03
Nitrogenized organic matter and salts of ammonia . . .	39·54	29·71	45·23	11·18	21·33
Biphosphate of lime .	12·97	14·42	15·40	28·33	24·45
Equal to bone-earth made soluble . . .	(20·24)	(22·46)	(24·02)	(44·20)	(38·14)
Insoluble guano phosphate	4·80	8·43	2·11	6·37	3·02
Sulphate of lime . .	19·07	5·29	22·86	32·68	31·23
Sulphate of magnesia .	...	4·76	...	...	...
Alkaline salts . .	8·34	3·62	4·37	5·38	3·14
Insoluble matters . .	3·98	5·64	1·76	1·96	2·80
	100·00	100·00	100·00	100·00	100·00
Containing nitrogen .	8·50	7·02	8·50	·51	2·31
Equal to ammonia .	10·32	8·53	10·32	·64	2·80

The choice of high-class and other manures was never so wide as at present, and with ordinary discrimination on the part of buyers, never could such good value in this shape be obtained as at the present time. The uncertain value of Peruvian guano has given a stimulus to the use of high-class compound fertilizers, many of which are found to yield as much as 15 to 20 per cent. of soluble phosphates, and 7 to 12 of ammonia, according to price. The high percentages of chemical fertilizing constituents are not, however, the only tests of merit in such cases,—a dry and powdery condition being also an essential requisite, while a judicious choice and blending of the sources of the

several constituents, contributes much, even in the case of comparatively low qualities of manures, to their effectiveness and profitable employment in the field.

From the want of sufficient knowledge amongst some classes of buyers as to what is dear or cheap in the shape of artificial manures, farmers are still to be found employing inferior or even worthless articles at prices which, although low in amount, are far above their value, while a really good article, offering ample money's-worth, but at a necessarily higher price, is persistently passed by. Buyers, still too often failing to perceive, that in all such cases, the price per ton is quite secondary to the quantities of actual plant food, and its practical results, obtained from a given sum.

Many other kinds of guano appear in the market from time to time, but of which there appear to be no regular supplies, and need not therefore be noticed at any length. Bolivian guano has been long known; that lately met with, is a rich and peculiar guano, containing, in addition to the ordinary guano constituents, a considerable proportion of nitrate. Angamos guano is a curiosity of rare occurrence containing sometimes over 20 per cent. of ammonia. Various kinds of Phosphatic guano were formerly much used for root crops, but of late it is widely known that as a rule the employment of such materials in their raw state is a wasteful and non-effective proceeding, although they furnish excellent insoluble phosphates

for compound manures, as already mentioned. Such guanos are now still used in the North, where on certain soils they are found to be effective. These guanos contain 30 to 70 per cent. of phosphate of lime, more or less pure, that is, free from admixture with oxide of iron, with small quantities of organic matter, furnishing a little nitrogen, mostly under 1 per cent. The amount of the latter is important over and above its actual agricultural value, inasmuch as it shows to what extent the guano is mineralized, its practical value being in proportion as it is unmineralized, that is, retaining its natural condition of chemically minute subdivision.

Guanahani guano is a new kind of guano lately imported in considerable quantity, especially in the North. It contains 30 to 35 per cent. of phosphate of lime, with a notable quantity of nitrogen—partly as nitrate, and which adds materially to its effectiveness in the field.

Nitrate of Soda.

In consequence of the lower price of this article of late, it has been more than ever used for spring top dressing, for which purpose it is admirably adapted. At the same time it should be borne in mind that this manure is a stimulant merely, and is likely to "draw" the land unless it is otherwise supported with phosphates and other elements of vegetable

nutrition. It may also prove a somewhat wasteful medium for expending money on nitrogen, inasmuch as all of it not taken up by the crop, is washed into the drains if exposed to heavy rains, owing to the non-retentive character of the soil towards nitrates; or in other words, the soil has little or no power of absorbing and retaining these salts, as it has those of ammonia.

There is reason for believing that all nitrogenous constituents applied as manure are converted into nitrates before being taken up by plants. Whether or not such conversion is essential to assimilation is not yet determined, but it has been shown by some important experiments, that a constant nitrification proceeds in the soil, and leads to a constant waste of its nitrogenous constituents for the reason above mentioned.

The frequent presence of nitrates in well water, often in considerable quantity, especially when contaminated by nitrogenous impurities (and which constitutes an indication of the latter circumstance), would also point to the ready conversion of nitrogenized organic matter into nitrates in the presence of earthy matter, calcareous matter, and moisture.

Nitrate of soda, when pure, is of very uniform composition—containing seldom more than 5 per cent. of total impurities, which is termed its "refraction." These impurities consist chiefly of common salt, with

sulphates, moisture, or insoluble matters. In consequence of its high price, however, nitrate of soda is often found adulterated, generally with common salt, as it is impossible to distinguish samples so mixed by any means short of analysis. The rough testing of nitrate sometimes recommended of throwing it on a fire is entirely fallacious, since the chloride of sodium has no effect that can reveal its presence, unless present in large quantity. A better rough test is to mix a little with vitriol, when any excessive evolution of the greenish coloured suffocating gas (chlorine) indicates admixture with common salt. Nitrate of soda containing much common salt is very objectionable for use in the manufacture of vitriol—since the chlorine liberated as above has a very destructive effect on the lead of the acid chambers.

Discoloured nitrates are often but little inferior in quality to the best, when *bona-fide* (see No. 3 in subjoined table), but of late it appears such samples are prepared for the market by unscrupulous dealers (No. 4). White samples of nitrate are by no means always the best, those having a brownish or pinkish shade are as a rule the better. The most adulterated samples generally have a fine white colour: No. 2 was an instance of this kind. No. 4 was offered as slightly damaged at £10. per ton, a price at which many would be likely to buy it as it was only slightly discoloured. Its value, however, was only about £5. per ton, and

this is all that was paid for it by my client on learning its actual worth. The high price of nitrates thus admits of serious loss, if we don't mind what we are about.

Nitrate of Soda.

	1.	2.	3.	4.
Moisture	·64	1·70	1·62	1·46
Nitrate of soda . . .	96·57	62·44	94·93	34·60
Chloride of sodium . .	2·37	33·26	1·40	61·50
Sulphates, etc. . . .	·42	2·60	6·3	2·20
Insoluble matter . . .	Traces	Traces	1·42	·24
	100·00	100·00	100·00	100·00
Refraction	3·43	37·56	5·07	65·40

Kainit

is a material of comparatively recent introduction, intended to supply potash to the soil—a material which had previously been of too high a value to allow of much being employed in this manner. Its addition in conjunction with other manures on light lands is calculated to be of service, and especially for potatoes, as referred to in speaking of special manures. Muriate of potash is also now imported as a concentrated source of potash, having about 80 per cent. Kainit contains about 23 to 25 per cent. of sulphate of potash, with salts of magnesia and soda.

Adulterated Manures.

So far we have noticed only manures of fair quality, but as well known, many of those offered to the notice of buyers are of inferior quality, and often adulterated. Such articles are generally offered at a lower price than good manures can possibly be got for, and it is with manures as with other goods, if we pay less than a reasonable price, we must expect to be taken in; hence in such cases there is the less sympathy for the sufferers. There are however, other so-called manures for which high prices are charged, and are even more worthless than low-priced ones, while numbers of inferior manures pass muster year after year, at the current prices of good ones, but which are much below in value and therefore yield an undue profit to their vendors, and against which it is as much the interest of respectable sellers, as of buyers to protest.

Chemists are sometimes blamed because a manure which they have analysed and reported well of may afterwards be found to be of lower quality, but it is a common practice amongst fraudulent dealers, especially in guanos, to have a sample analysed before they adulterate it, and then represent such analysis as showing the composition of the bulk. This is an injury to which all chemists of any note are subject and against which they are of course powerless. The

only safeguard against the integrity of samples being the reputation of the dealers, and which is of course of no avail if bargains are sought after from unknown dealers.

Nothing can be a greater fallacy on the part of farmers than to suppose they can judge of the quality of a manure as they can of a sample of corn, or by its appearance, smell, feel, &c. After a very wide experience on this subject I can unhesitatingly affirm that it is absolutely impossible for any one, whether chemist or not, to form any reliable opinion of a manure in this manner. In the case of adulterated guanos especially, I have been often astonished at the excellent external resemblance to genuine Peruvian, by some perhaps grossly inferior sample: the fact being that the art of adulterating guano has been well studied, and reached a high degree of perfection, and showing that the trade must be a remunerative one.

While it is thus the fact that there are many adulterated and inferior manures in the market, and that buyers should be on their guard against purchasing them; we should avoid falling into the absurd doctrine taught in some quarters that all manure manufacturers are rogues and making fortunes out of the pockets of the farmer. A simple calculation of the cost of raw materials, the large capital required for the erection of works, and to give the credit expected by the majority of buyers, cost of labour, carriage, bags, &c., will

show that when the manures are supplied of the quality represented, and it is the farmer's own fault if they are not, the net profit obtained by the maker is by no means excessive, in fact considerably less than is expected in many other trades in which large capital is expended.

The following examples of adulterated manures, analysed by me, will sufficiently illustrate this portion of the subject; and are selected from many others I constantly receive.

Composition of Adulterated Manures.

	No. 1.	No. 2.	No. 3.	No. 4.
Moisture	13·17	9·34	24·10	28·13
*Organic matter, etc. .	6·94	6·36	13·12	11·36
Biphosphate of lime .	3·59	Traces	Traces	Traces
Equal to bone-earth made soluble	(5·60)	...	...	...
Insoluble phosphates .	16·14	10·13	8·13	7·13
Sulphate of lime . .	30·27	17·80	12·48	33·98
Alkaline salts . . .	3·05	3·14	2·04	
Insoluble earthy matters	26·84	52·23	40·13	26·43
	100·00	100·00	100·00	10·000
*Containing nitrogen .	·28	·61	·68	·68
Equal to ammonia . .	·34	·74	·83	·77

No. 1 was analysed with several others for the Milborne Farmers' Club. It was called a turnip manure and sold at £7. per ton—its real value being about £2. 10*s*. This analysis affords an instance of

the kind of inferior manure above mentioned which may pass muster as a fair manure, since it contains quite enough fertilizing material to make some show on the crop, and it is quite possible for a farmer to rest under the impression that he is getting fair value for his money. Yet here is a yearly loss of £4. 10*s* per ton, and if all manures were like this, we might well cry out against the profits of the makers. Makers oi such manures are often as ignorant of their real value as the farmers they supply, and prepare them in the most unscientific and uneconomical manner, and yet may fully believe they are supplying a really good article at a fair price. The evil however is of course none the less on this account, nor in less need of alteration.

No. 2 is a curiosity in the way of superphosphates so-called, as it will be seen to contain traces only of soluble phosphates and not much insoluble, and more than half its weight of sand. It was analysed amongst several others for the Newbury Farmers' Club. I was not informed the price at which it was sold, but as its value is at the most not more than twenty shillings per ton there would doubtless be a heavy loss upon it, and in these cases where little or no manurial effect can be expected, the loss of crop is often as serious as the loss of the money paid for them.

No. 3 is somewhat similar to the foregoing but it had a dark colour and very strong smell, a point which

is generally suspicious in such articles, but supposed to have virtue in attracting the unwary. This sample will be seen to have 40 per cent. of sand, and little else of any value. It was sold at £5. per ton, its value being about 15*s*; this sample was analysed by me for the Dorchester Farmers' Club. No. 4 was sent from the neighbourhood of Norwich, and is worth only 25*s* to 30*s* per ton.

Another sample, the analysis of which is not to hand, was one of the high-priced articles before adverted to, being but little under Peruvian guano. It consisted chiefly of worthless alkaline salts, earthy matter, and sulphate of iron, with traces only of phosphates and ammonia. In this case payment for more than its value, as shown by my analysis, was refused; the sellers thereupon threatening an action-at-law for the balance, but which was abandoned as soon as they found the buyer was not frightened thereby. In cases like this a buyer does good service by exposing such a fraud, especially to his brother farmers of small means who are generally the greatest sufferers through these adulterated manures. Other samples of adulterated nitrate of soda will be found under that heading, this article, from its high price and easy admixture with common salt, being very commonly selected as the medium of fraud by adulteration.

Against adulterated or inferior manures, buyers have entire protection—1st, by dealing only with persons of

respectability and standing, and having a guarantee as to quality; and 2ndly, by having the bulk delivered analysed, or at least tested for the chief constituents, by a competent chemist. This can be done at small cost, especially if a few neighbours act in concert, and to grudge the cost of an occasional analysis is very false economy indeed, as it is frequently the means of saving as many pounds as it costs shillings or even pence.

Even in the case of manures supplied by respectable firms the bulks delivered are not always quite up to the guarantee, either through some accident arising from a pressure of business, or from the difficulty of getting mixed manures uniform throughout the entire bulk; in which case a *bona fide* cause of complaint is always entertained, and such complaint is only a reasonable proceeding before assuming that we have been cheated.

CHAPTER V.

VALUING MANURES.

ALTHOUGH I do not approve of the practice of chemists attaching their valuation to their analyses unsolicited, and do not do so myself unless specially requested, since chemists, however able, cannot be allowed to be the best judges of commercial questions of this kind, yet it is at times unavoidable and necessary for them to fix a money value to the samples they analyse, and it is very desirable for all parties that in such cases the valuation should be just and reasonable. As buyers and sellers also frequently desire to have some means of ascertaining approximately for themselves the relative values of two or more samples of which they have the analysis, I prepared a scale of prices for the principal constituents of manures some time since, and which has been widely adopted. I have now modified this scale, so as to render it generally suitable for the present time under the circumstances mentioned, and as any scale of this kind must needs be more useful for comparative purposes than for arriving at the actual commercial value of a sample, strict accuracy is not needed nor intended. It would obviously be impossible to devise any scale which would give correct results in all cases, since to begin with we should want a separate price for every source

of the principal constituents, and we should still have to meet the difficulty of finding out how much came from one source and how much from another—points on which the ordinary results of analysis throw no light. As well known, however, the sources of the constituents of a manure have much to do with its practical efficiency, especially in the case of the most costly item, viz., ammonia or nitrogen, which, as well known, may exist in a form not only useless, but positively injurious. These points can, of course, only be ascertained with certainty by a chemist sufficiently experienced in such matters on making the analysis, and he can only say in such cases what he considers a fair value for the sample. In the great majority of cases, however, any one can obtain a good idea of the money value of a sample from its analysis and inspection, by means of the following table, which is based on a careful consideration and comparison of the composition and prices of the good samples in the market.

After due consideration it is thought best to have two prices for soluble phosphate, one in the form of good dissolved bone manures, and another for mineral superphosphates, even though the soluble phosphate in the former may be derived in part from a mineral source. From the greater difficulty and cost of dealing with bones and getting them into a saleable condition, which is augmented in proportion as they are of higher quality, the above course is unavoidable

without going wrong on one side or the other, since the price at which ordinary soluble phosphates from minerals can be produced, would be obviously unremunerative for the better class of bone-manures. Some persons may say it ought to be made at the same price, but this is a point which may now be considered as settled by the laws of supply and demand. If buyers want a really good dissolved bone they must pay the market price for it, which, it may be taken, is the lowest price at which it can be made, since there is no lack of competition in the trade.

The circumstances under which manures are sold must also be understood in quoting or comparing their money-value; thus a price on which the buyer has to pay carriage cannot be compared with one in which this item is included: or if the buyer does not pay for a twelvemonth or longer after they are bought, he cannot compare his prices with those for ready-money or even prepayment. The following scale is intended to apply to the purchase of manures under the circumstances usually prevailing in agricultural districts, where they are supplied in bags and carriage paid and credit given. When bought in quantities, in bulk, for ready-money, or fetched from the works, of course a lower scale would apply.

Again, the physical characters or "condition" of manures must be taken into account in estimating their money-value. Those in which this matter is specially

attended to (and it is one in every way worthy of attention) are obviously worth more than those in which it is neglected, or even comparatively so. As a variety of circumstances also affect the prices in particular districts, it will doubtless be found that the following scale will give values a little over the market price in some districts and under in others, a fair general average being aimed at.

At the following prices for the phosphates and nitrogen, the gypsum, organic matter, &c., may be left out of consideration (except potash), although they possess a small but definite value.

Scale of prices per unit for:—

	s.	d.
Soluble phosphate	4	6
Ditto in mineral superphosphates . . .	4	0
Precipitated phosphate	3	6
Insoluble phosphate, as bone, or from guano .	2	6
Insoluble mineral phosphate up to 7 per cent. .	1	0
Potash, sulphate	3	6
Ammonia*	18	0

* Now advanced to 20*s*, see few pages hence.

An example or two will render the use of this scale clear. We may take a high-class dissolved bone-manure and a mineral superphosphate of good quality. These will have about:—

	Dissolved bone.	Mineral superphosphate.
Soluble phosphate .	20 — 22	25 — 27
Precipitated phosphate .	2 — 3	traces
Insoluble phosphate as bone	10 — 12	(mineral 5 — 7
Ammonia	1·50 — 1·75	traces

This composition in round numbers may be taken as fair examples of the kind named, but many samples will be found over and some under, although the market price may be the same,—it being convenient in practice to state a fixed price without regard to small variations when within given limits. The mean of the dissolved bones will be :—

					s.	*d.*
21	units	soluble phosphate . .	at 4/6	=	94	6
2½	„	precipitate phosphate .	at 3/6	=	8	9
11	„	bone phosphate . .	at 2/6	=	27	6
1·62	„	ammonia . . .	at 18/-	=	29	0
(Any Fraction under 3*d* may be omitted.)						
		£7. 19*s* 9*d*.			159	9

The mean of the mineral superphosphate will be :—

					s.	*d.*
26	units	soluble phosphate . .	at 4/-	=	104	0
6	„	insoluble mineral phosphate	at 1/-	=	6	0
		£5. 10*s* 0*d*.			110	0

In freshly made samples the precipitated phosphate is comparatively unimportant, and may be passed over without serious detriment; but in longer made samples, such as in the case of dissolved bones are unavoidably occurring in commerce, it is often a matter of importance; and its omission is especially hard upon the better qualities, which, for reasons I have explained on former occasions, are particularly liable to the conversion of their soluble phosphate into precipitated phosphate through the action of animal matter

and the undissolved bone, &c., and which cannot be prevented by any known means. Hence a sample which has been kept some months, and is practically as good (or perhaps better, since there is less free acid) as when freshly made and found to analyse up to the desired standard, may, if now analysed and valued without regard to the soluble phosphate so reduced, be estimated at a price quite inadequate to its value. Thus, if we take the example of dissolved bones before calculated, and suppose it to have become thus changed as under, a rather extreme case perhaps, but by no means uncommon, say:—

Soluble phosphate	17
Precipitated phosphate	6½
Insoluble phosphate	11
Ammonia	1·62

Its valuation would be according to above scale:—

					s.	d.
17	units soluble phosphate . .	at 4/6	=		76	6
6½	„ precipitated phosphate .	at 3/6	=		22	9
11	„ insoluble phosphate .	at 2/6	=		27	6
1·62	„ ammonia	at 18/-	=		29	0
	£7. 15s 9d.				155	9

On the other hand, if the precipitated phosphate be discarded, we have:—

					s.	d.
17	units soluble phosphate . .	at 4/6	=		76	6
17½	„ insoluble phosphate .	at 2/6	=		43	9
1·62	„ ammonia	at 18/-	=		29	0
	£7. 9s 3d.				149	3

Thus over and above the natural deterioration by keeping consequent on the different commercial value between soluble phosphate and precipitated phosphate, and amounting in this instance to *4s* per ton, we have also a further loss of *6s 6d* through a defective mode of analysis. It will be noted that this supposed sample is of superior quality and its price high: the average will be under this, and the price consequently less able to bear reduction from this cause.

Mineral superphosphates are less liable to deterioration from this cause, as by a judicious selection of raw materials it can to a great extent be avoided—yet, under certain circumstances, as by long keeping, a material loss may here also accrue.

It may be added that the formation of precipitated phosphate is admitted by all who have any experience of the subject, and is now determined by more chemists than formerly, especially on the Continent; yet there is and has been great hostility shown towards its recognition in some quarters, for reasons which need not be entered upon here; suffice it to say, that while some pooh-pooh it altogether, others assume to have proved that untrustworthiness of the means suggested for its approximate determination, by trials in which the conditions of success have been obviously omitted.

The identification of this form of phosphate being thus often a matter of importance, I now give its approximate amount when so requested; at the same

time I should plainly state that I consider it distinct from soluble phosphate, and when a definite percentage of the latter is bargained for, it cannot properly be included unless the contract is to that effect.

Nevertheless, as manufacturers do not appear disposed to press their rights on this point, some modification of the foregoing scale is necessary to render it generally useful and applicable in those cases in which the precipitated phosphate is not shown, either from the refusal on the part of the analyst to recognize it, or from a simpler and less complete analysis only being desired. In the latter case I can generally form an opinion from the appearance of the sample while undergoing examination as to whether the precipitated phosphate is much or little. I therefore propose to take the whole of the insoluble phosphates, in the case of well-made bone manures, at 2*s* 9*d* per unit, which will be found to bring the value pretty near to that obtained as above, the only difficulty being in deciding whether a particular sample is worthy of being thus classed. This may be judged—1st. By its appearance as to colour, smell, and the amount of visible bone fragments present; these are most effective when of moderate size and friable, that is capable of being easily crumbled. 2nd. By the proportion of ammonia which, as a rule, indicates the proportion of bone present: thus a sample with less than half a unit of

ammonia can only contain a small proportion of bone, and the small proportion of ammonia often present in mineral superphosphates (derived from the acid) does not necessarily indicate bone. From half to one unit would indicate a good proportion of bone, while the best would contain, as above pointed out, 1½, 1¾, or even 2 per cent. of ammonia. It is true this may be supplied from other sources, but if, as more commonly the case, it is from animal matter, or sulphate of ammonia, this is no detriment, and the rule is fairly applicable. A trial of this plan on the example already taken will afford a comparison, thus —

					s.	*d.*
21	units	soluble phosphate . .	at 4/6	=	94	6
13½	„	insoluble phosphate .	at 2/9	=	37	0
1·62	„	ammonia . . .	at 18/-	=	29	0
		*£*8. 0*s* 6*d*.			160	6

Or for the same sample after alteration by keeping:

					s.	*d.*
17	units	soluble phosphate . .	at 4/6	=	76	6
17½	„	insoluble phosphate .	at 2/9	=	48	0
1·62	„	ammonia . . .	at 18/-	=	29	0
		*£*7. 13*s* 6*d*.			153	6

Thus we perceive that this plan agrees closely with the former standard in ordinary samples, but comes under the valuation obtained by the separate determination of precipitated phosphates in the case of samples rich in this constituent. In adopting this plan

care must be taken that the insoluble phosphate does not contain undue proportion of undecomposed phosphate other than bone, as frequently occurs in the lower qualities of bone manures. On this point a few more words are perhaps necessary. We have seen that the percentage of ammonia is a general indication of the proportion of bone, this may be more explicitly stated thus: 1 per cent. of ammonia may be taken to indicate about 10 to 12 per cent. of bone phosphate, and so in proportion, a percentage of ammonia equal to that in the foregoing example will indicate more than sufficient bone for the whole of the insoluble phosphate, although some of it may be amongst that decomposed by acid.

As regards the proportion of the precipitated phosphate, it may be taken that, except in the case of high-class dissolved bones which have been made some time, it is not likely to exceed 2 to 3 per cent. in ordinary cases.

Although intended more especially for manufactured and special manures, we may now try this scale on Peruvian guano, and so test its approximative correctness, or at least ascertain whether its prices are well within those applying to this manure, which being under the control of one Firm, and sold at one price throughout the country (except so far as affected by cost of carriage), may be taken as a fair standard. Peruvian guano may at present be taken to average

about* 11 per cent. of ammonia and 28 of phosphate of lime, although many samples are under this and some over—its extreme uncertainty being at present the chief objection connected with this valuable manure. Hence:—

				s.	d.
28 units guano phosphate . .	at 2/6	=		70	0
11 " ammonia	at 18/-	=		198	0
	£13. 8s 0d.			268	0

This valuation is thus considerably below the present price to retail buyers under the circumstances applying to this scale.

The foregoing pages are reprinted verbatim from the paper issued by me last year, which it is thought best to leave unaltered, and by the reception of which I have been much gratified, it having met the approval generally of both buyers and sellers, and been very favourably recommended by the Press, as supplying a want often felt, in a satisfactory manner. The difficulty has always been to fix a price for soluble phosphates sufficiently high to give a fair value for the better class of manure, while not too high for dissolved mineral phosphates merely. This difficulty appears to me insurmountable, except by the expedient I have adopted of two prices for it in these two forms, as in my scale, and which so far as I am aware has not been adopted

* This is rather above the present average for ammonia.

before. I should add that, except in the case of a constituent in two well-marked and easily distinguished conditions, it is not desirable to admit the principle of different prices for different sources of the same constituent, as it would be likely to lead to endless confusion.

As the prices of raw materials have not materially altered since last year, except in the case of ammonia, which has advanced, I think it advisable to retain the prices of the phosphates, &c., unchanged, and to advance the price per unit for ammonia from 18*s* to 20*s*; so that the scale will now stand as under.

PRICE PER UNIT FOR :—*

	s.	*d.*
Soluble phosphate	4	6
Ditto in mineral superphosphates	4	0
Precipitated phosphates	3	6
Insoluble phosphate, as bone or from guano	2	6
Insoluble mineral phosphate, up to 7 per cent.	1	0
Potash, sulphate	3	6
Ammonia	20	0
Insoluble phosphate in good dissolved bones (when precipitated phosphate is not given)	2	9

With reference to the complaint sometimes made by manufacturers against the unjust valuation of their manures by chemists, I think such complaint is on the

* It will be remembered that the above prices are intended to apply to the purchase of manures under the circumstances usually prevailing in agricultural districts, where they are supplied in bags, carriage paid and credit given. When bought in quantities, in bulk, for ready money, or fetched from the works, of course a lower scale would apply.

whole well founded, seeing it is unfortunately true that many chemists either do not take sufficient care to acquaint themselves with the various practical details of the manufacture which are items of cost, or for other reasons, appear to be unconscious of or indifferent to the importance of the matter to those concerned. In fact it would seem, from cases that have from time to time come under my notice, that there are some chemists who affix their values in an arbitrary manner, which is quite unreasonable, and which it would be impossible for them to substantiate if put to the proof. This is much to be regretted, as it is of course calculated to bring the whole thing into discredit, and in which of course all must suffer.

It is true farmers should by this time know enough of the subject to avoid being misled in this manner, and to be able to judge of a manure from its analysis on its own merits, and which some doubtless do, but there are still many farmers who know very little about analysis, and who rightly or wrongly look upon the chemist's valuation as the key thereto, without which it is to them of no service, and in many cases will not accept it without.

It is for this reason that it is useless to say chemists ought not to give the valuation at all of samples submitted to them for analysis. For my own part I never do so unless specially requested (and then for private guidance only), but if I were then to refuse, it would

simply be sent to some one else, who might be less competent to do so. In such cases, therefore, I supply the valuation as requested, taking as a basis the scale above given, but also at times modifying it somewhat according to the sources of the constituents, condition of sample, &c. My valuations thus arrived at have, I am happy to say, been accepted in numerous cases as perfectly satisfactory to all parties.

I am therefore of opinion that what is needed is not so much the non-valuation of manures by chemists (although for the reasons pointed out at starting, they ought not to be expected to give it) as that they should give when they do so, a valuation that is just to all parties and approximately correct under the circumstances attaching to the sale of the manure, which it is very important should be understood.

It will be seen that this plan of taking a fixed price per unit is even simpler than the older plan of taking so much per ton for each constituent of 100 tons. For the sake of comparison, the following scale and example may be quoted, as published by me some years since, and which represents the prices used by the best authorities and myself at the time: it will be seen to be too high in the phosphates and too low in the ammonia for the present market prices. The example also illustrates the improvement made of late years in the composition of phosphatic manures: this being then considered a good superphosphate.

"By a careful consideration of the prices at which the different constituents of artificial manures can be purchased separately, or in other forms, we arrive at the money-value of a ton, or any other given quantity, of each particular constituent, and can now calculate the value of the quantity present or in any given quantity of superphosphate. The prices above adopted are as follows:—

Soluble phosphate (phosphate rendered soluble)	£30	per ton.
Insoluble phosphate of lime (in form of bone)	10	„
Ammonia	60	„
Gypsum (sulphate of lime)	1	„
Organic matter	1	„
Alkaline salts (salts of soda)	1	„

"Earthy or sandy matter and water are generally left out of consideration, but when the amount of either of these constituents is abnormal, as in adulterated or very badly prepared samples, a reduction has to be made in the total value for the cost of carriage of this useless material.

"The calculation is most conveniently made by taking the analysis (as stated in 100 parts) to represent 100 tons of the manure, and multiply the amount of each constituent by its own price per ton—the result gives the value of the quantity of this item present, and the total of these sums, the entire value of the 100 tons, and this divided by 100 gives the value per ton. An example will render this clear:—

Water . . .	20·53			
*Organic matter .	14·76	tons at	£1	. 14·76
Bi-phosphate of lime	10·31			
Equal to bone-earth	(16·09)	„	30	. 482·70
Insoluble phosphate	17·72	„	10	. 177·20
Gypsum . .	28·39	„	1	. 28·39
Alkaline salts .	1·56	„	1	. 1·56
Insoluble earthy matter	6·73			
	100·00			704·61
*Containing nitrogen (equal to ammonia)	1·06	„	60	. 63·60
				768·21 per 100 tons,
				or
		£7. 13*s* 7*d*.		7·68 per ton."

Finally, it should be added that however, or by whomsoever, valued, too much importance should not be attached to small differences when manures are analysed one against the other even by competent chemists; since the chemist can of course only judge from the sample submitted to him, and as well known by those who have had experience in the matter, great care and some special knowledge is requisite to divide samples properly, and from the neglect of which, a good manure may possibly be brought into discredit. When two or more samples are taken at one time too much care cannot be taken to avoid getting them confused as to numbers or marks.

A word as to sampling manures may not perhaps here be out of place, as although the matter is now pretty well understood by buyers and sellers accus-

tomed to deal by analysis, it is often strange to farmers. The following directions are what I have had printed on all my papers used for public circulation, &c., and cannot be too widely known.

"In taking samples of manure, &c., several portions should be taken from different parts of the bulk, or from different bags, and the whole thoroughly mixed, and all lumps chopped down with a table knife on a clean sheet of paper. Smaller portions should then be collected from this in the same manner, until a manageable quantity is obtained, of which 2 ozs. to 4 ozs. is amply sufficient to send for analysis. Large samples may be divided in the same manner.

"I would beg to direct the attention of those who do not already adopt the practice, to the advantages of the present Postal Rate for Sample Packets, which can now be sent (sealed or unsealed) at much less cost than by Rail or Parcels Delivery, and by which a great saving of time is effected—the samples being thus delivered with the advice, and all second charges by carriers avoided. The cost is 2*d* only, under 4 ozs. which is sufficient to send if properly taken from the bulk; and it should be remembered that a larger sample does not dispense with care in this particular. Tin or wooden sample boxes can be so sent, but paper (two or three wrappers) is generally sufficient. Cakes should be sent in unbroken pieces of the above weights. All packets should be marked on the outside to allow of identification."

CHAPTER VI.

USING MANURES.

The commonly received rule, of nitrogenous or ammoniacal manures for cereals, and phosphatic manures for roots and green crops, is, like many other rules, only broadly applicable, since it is now beginning to be recognized that a free use of available phosphates as well as nitrogen is the best treatment for the former, while a judicious addition of nitrogen to the soluble and other phosphates applied to roots, is found to be the most profitable procedure. Hence all that this rule amounts to is that we may use more nitrogen and less phosphates for cereals, and more phosphates and less nitrogen for roots. Thus Peruvian guano, which is usually placed at the head of ammoniacal or cereal manures, contains 25 to 30 per cent. of phosphate of lime (most of which is in the chemically divided or precipitated state, and therefore decomposable by oxalates, as pointed out by Liebig), besides 3 to 5 per cent. of alkaline (soluble phosphates), and to which much of its efficiency is known to be due; while dissolved bones, containing $1\frac{1}{2}$ to $1\frac{3}{4}$ per cent. of ammonia, is the most effective manure for roots, or

when mineral superphosphate only is employed, a dressing (the heavier the better) of farm-yard manure is added if possible.

The character of the soil is, as is well known, an important element to be taken into account in the choice and application of manures. The general difference between strong and light soils may be taken to be that the former contains a larger store of the natural elements of fertility, though for the most part in an undeveloped state, while from an excess of clay the physical property of retentiveness and its consequent drawbacks are too prominent; while light soils, on the other hand, are comparatively deficient in natural resources, and by reason of a deficiency of clay, possess the property of porosity in a too great degree, and hence afford a too ready passage for water and other bodies necessary to vegetable growth.

On stiff clay soils we have all the defects arising from the tenacious and plastic properties of clay, and its consequent imperviousness to water, hence the first necessity towards the improvement of such soils is thorough drainage, in order to remove the excess of water, and without which the best manures will have but a meagre effect. All means of adding to the porosity of such soils are to be recommended—one of the best of which is burning in heaps with vegetable refuse, or small coal or breeze, in the manner "ballast" is burnt, and which, spread over

the land before ploughing, has an excellent effect in lightening the soil. It is of course on these soils that steam cultivation is of such especial value since it allows of a thorough breaking up and stirring at favourable times, particularly before frost, which, properly assisted, does more for strong clay soils than almost anything else. In fact, cultivation on such soils must always be the primary resource for advancing their fertility—but supplemented, of course, by a judicious selection and application of manures.

On strong clay soils nothing can be better than the free use of nitrogenous manures, and although such use may entail a considerable outlay, it will in the great majority of cases yield a good return, proper care being taken that manurial worth is obtained for the money expended, and that it is applied in the manner best calculated to afford the best result which the character of the season will admit of. We are all negligent at times, and farmers often lose a valuable opportunity of assisting the crops at the right time through being too late in providing themselves with the requisite manure. As above hinted, a more extended use of phosphates in conjunction with nitrogen for corn crops on such soils is found beneficial; and I should advise a mixture of superphosphate with nitrate of soda (which is a purely nitrogenous manure) whenever this manure is used, and as it may be used in part substitution, there would of course be a saving of cost as

well as better practical result. Nitrate of soda has been very extensively employed of late in consequence of its comparatively moderate price; but it should always be remembered that it is a stimulant merely; it supplies nothing to the crop but nitrogen, and therefore differs very materially from Peruvian guano, as above pointed out. It should also be remembered that if not taken up by the crop to which it is applied, it is not likely to remain over for the subsequent crops, as is the case with guano and most other manures. This is because the soil possesses no power of absorbing nitrates which are washed out by rain into the drainage as already mentioned. It may be added that this leads to a constant waste of nitrogen from other sources, which is constantly being converted into nitrates by the action of the soil, especially on "hungry" soils, which derive little benefit from the manure applied. For the same reason it is a mistake to put nitrates in corn manures intended for autumn sowing—although a small dressing of dissolved bones at this time, when nitrate is intended to be used in the spring, has an excellent effect. I should say $\frac{1}{5}$th to $\frac{1}{4}$th superphosphate to $\frac{4}{5}$ths to $\frac{3}{4}$ths nitrate, using the mixture at the same rate as nitrate is usually employed alone: there is no objection to using salt as well if preferred. Nitrate and superphosphate may be mixed without injury if the latter is moderately dry and without much free acid, otherwise it must first be

mixed with a little gypsum or fine ashes before the nitrate is added, or there is a possibility of loss through the decomposition of the nitrate. This, however, seldom happens, as many of the best special corn manures in the market contain nitrate as well as much soluble phosphate, and which, by the way, gives much additional trouble to the analyst, for the reason before mentioned.

Clay soils differ widely as to the natural resources of fertilizing elements they are capable of yielding, and consequently as to the course of management that should most profitably be pursued in their management. This is one of the problems which can be solved by analysis; and numerous cases have come before me of substantial benefit being derived from an analysis or partial analysis of soils.

In sandy soils, on the other hand, we find all the defects arising from an extreme porosity, or in other words an absence of retentiveness consequent on the paucity or absence of clay, which is the chief storehouse, so to speak, not only of the moisture of the soil, but also of the plant food, either artificially added or derived from natural sources, and from which the roots of the plants draw their supplies as required. An addition of clay in such cases, where practicable, is of great service, care being taken to ensure as far as possible its even distribution by drying and pulverizing, otherwise it remains in clods long after

application. The retentiveness of such soils may be enhanced by green manuring, which is an excellent resource in many such cases, and deserves to be more extensively adopted, as we thereby obtain a clear gain of nitrogen from natural sources, and at the same time gather up and preserve any nitrates present in the soil, in a staple and efficient form; while the humous compounds arising from the decay of the vegetable matter afford an absorbent for moisture, &c., in the same manner as clay. Phosphates supplied to such crops are well expended, since they are returned and preserved for future use in the soil in a shape highly favourable for the nutrition of following crops. Where it is not practicable, or thought advisable to devote the whole of the crop to manure, we may adopt the principle to some extent by leaving over as much as can possibly be spared for ploughing in. That vegetable matter in a readily decomposable state is a valuable form of manure is shown by the character of the wheat crop following a clover lea: where the clover has been successful, the wheat as well known generally corresponds, and *vicè versâ*. I am disposed to think that organic matter or vegetable remains in the soil, have been undervalued of late in a chemical point of view, and that the amount of such organic matter present, coupled with the amount of available nitrogen it contains, may be taken as a good indication to the state of fertility of the soil. Clover is a particularly valuable crop

in this respect where it can be grown, as in consequence of its large development of root, it affords a clear gain of nitrogenous organic matter to the soil, apart from its produce above ground.

The leaves and refuse of all green crops not consumed as food should be carefully returned to the land, as they are rich in manurial elements in the best possible state for future use when prepared by decay in the soil, and should moreover be evenly distributed over the field before ploughing in: the neglect of this is often shown in a crop of corn following roots, in which regular patches mark the spots where the leaves, &c., had been thrown in preparing the roots for stock, and which receive an excess of nitrogen, &c., at the expense of the crop generally. We may take it as a general maxim not to burn any refuse that will rot in the soil (except in the case of foul turf infested with insects, or seeding weeds, &c.) since by so doing we lose the nitrogen and organic matter, besides rendering the ash-constituents less available by mineralizing them.

Lest the foregoing remarks respecting green manuring may be thought to be at variance with the maxim that we should never use as manure what can first be used as food, it may be added that under exceptional circumstances, as in the case of the light sandy soils under notice, vegetable produce may be more valuable as manure than as food, by conducing to

a physical improvement of the soil, and consequently to a higher degree of fertility.

On sandy soils nitrates should be especially avoided, on account of their ready removal by rain in the manner before noticed. Ammoniacal salts also should be only sparingly employed, the best form of nitrogen in such cases being nitrogenized organic matter, especially as it occurs in a well-made dissolved bone manure, than which there is no better dressing for soils of this description. Crushed bones alone are often employed with advantage, but the former I consider are preferable, those with a higher proportion of bone, than for ordinary use, being suitable. Rape dust is also a good source of nitrogen for such soils; also dried fish or other animal matter containing nitrogen in a form not easily wasted through the non-retentiveness of the soil.

Rape dust is also a valuable manure for general use, and when of good quality, that is, containing 5 to 6 per cent. of ammonia (nitrogen equal to), one of the cheapest. Any kind of rape cake which from an excess of mustard or other reason is unfit for feeding, can be used for this purpose. For moderately light soils a mixture of equal parts of rape dust, superphosphate, and guano is an excellent corn manure: or for spring use nitrate of soda may be substituted for the guano. Damaged cotton cakes are also at times procurable at a fair price, and are equally serviceable as rape cake.

The following analyses, with reports thereon for supplying the information sought to be obtained respecting these particular soils, may here be quoted in illustration of the foregoing remarks:—

COMPOSITION OF A SANDY SOIL.

In air-dry state:—

Moisture	1·30
Organic matter and water of combination	5·13
Oxide of iron and alumina with traces only of phosphates	6·24
Carbonate of lime	2·93
Magnesia and a little potash	1·60
Silica and insoluble silicates	82·80
	100·00

"This soil is of a poor sandy character, and could not by any application of manure at once be rendered very fertile. I should recommend for corn crops a mixture of dissolved bone, rape dust, and kanite—say, 2 parts of each of the first to 1 part of the latter. The dissolved bone for this purpose should be of the best description, that is, containing animal matter as well as bone, so as to yield at least 1¾ to 2 per cent. of ammonia with not less than 20 of soluble phosphate — 13 to 14 of insoluble phosphates. A light top dressing of nitrate might also be used if necessary. I believe root crops and seeds could be grown with better success on this and similar soils if more liberally manured—say, with a dissolved bone as above, and not sparingly applied. This would gra-

dually increase the fertility of the soil for corn. Soils of this kind are frequently also deficient in lime, in which case its application is desirable. In the present case sufficient lime is present, although it occurs in isolated portions, and would be better if more uniformly diffused."

The above is an example of a partial analysis of a soil, and can be had at a comparatively small cost. The following complete analysis, with extracts from report, is selected as a good example of a strong clay soil (with which is also shown a peaty soil), made with several others, of soils from the West Indies, and although the report refers to colonial crops, the remarks apply substantially to soils of the same character in this country.

Composition of a Strong Clay Soil and Peaty Soil.

	No. 9.	No. 8. Peaty Soil.
Moisture	1·24	4·17
Organic matter and water of combination	5·13	71·32
Oxide of iron and alumina, with phosphoric acid equal to phosphate of lime	10·32	4·43
	·12 ...	·04 ...
Lime	Traces	6·70
Sulphuric acid	·25	Traces
Magnesia	·37	·34
Potash	·40	·26
Soda	Traces	·12
Silica and insoluble silicates	82·30	12·66
	100·00	100·00

"The great defects in these soils generally is a too adhesive character consequent on a superabundance of clay and a deficiency of lime. The proportion of this body in the best of these soils is lower than should be present in a really fertile soil, while in the majority it is unusually low, and in many cases so little as to be inappreciable to the most delicate chemical balance. Its addition in all these cases would therefore be desirable, and this may be done by the use of any kind of calcareous material that can most readily be obtained, such as shell sand, limestone rock, coral rock, marl, &c., all of which contain lime in the form of carbonate. These materials would also have a further beneficial effect in adding to the porosity of these soils, sand especially, freely applied, being likely to exercise a marked influence as a mechanical manure; also ashes of any kind.

"If none of the above calcareous materials can be advantageously obtained, the use of real or caustic lime (as used for building purposes) may be advised. This should be placed on the land in heaps and allowed to slake spontaneously, that is, become hydrated by absorbing water from the air by which it falls into fine powder, in which condition it can be evenly distributed over the land. In using lime in this manner, one precaution must be especially observed, viz., to allow a sufficient time to elapse between its application and

that of any ammoniacal manures, such as above advised; since, if this be neglected, much of the ammonia may be lost, lime having the property of decomposing all salts of ammonia; at least six months' interval should be allowed. In using lime in this manner, I should advise its application in a few experimental plots before going to any great expense in importing it largely. I may add, that the sample of peaty soil, A. No. 8, if procurable in quantity, is well suited to be used as a source of lime, either in its natural state, or if burned, in the former condition its organic matter would also materially benefit many of these soils in which this constituent is wanting.

"As regards the adhesive character of these soils, any treatment which tends to reduce this property may be employed with advantage, as above mentioned, and as about to be suggested. From the want of porosity and friability in these soils, the air and moisture is prevented from circulating through them, and hence the natural processes of preparing the elements of fertility for the food of plants, which are dependent on this action, are but feebly exercised.

"For improvement in this particular, I think the use of burnt clay worthy of trial. It should be burnt at a low temperature, in heaps, in the manner of burning 'ballast' for railways, or by means of small coal, or 'breeze' as it is termed. Any kind of vegetable

refuse would answer the purpose, if procurable in quantity. The clay thus burnt has lost its plasticity, or no longer becomes tenacious by water, and is thus well adapted for admixture with the natural soil for the above purpose, while at the same time it acts as a gentle manure, the processes of decomposition of its dormant constituents having been accelerated by the fire.

"It might also, perhaps, be worth a trial to apply the crushed cane, cut in short lengths, to the land with the above object. I make this suggestion in view of the fact that one of the chief points of value in farmyard dung for clay land is the mechanical effect of the straw, which is found to be more effective when thus ploughed in, in its fresh state, than when rotted as dung.

"It must also be borne in mind that in cases of soils of this character, the mechanical cultivation is as important, or more so, than the application of manure.

"In crude undeveloped soils much working in this manner is necessary to make them remunerative at all, while to attain a high degree of fertility, a constant and costly process of cultivation is requisite. Judging from the samples now reported on, I should conceive that the use of steam cultivation would be found admirably suited for this purpose, if the nature of the ground would at all admit of it. I mention this,

because the full remunerative effect of the manures above recommended is not likely to be obtained, unless supplemented by a proper condition of the soil.

"The mixture I have mentioned as No. 1, I would advise to be made of $\frac{2}{3}$ superphosphate and $\frac{1}{3}$ sulphate of ammonia. Mineral superphosphate (the cheapest form of soluble phosphate) might be used, and a second quality of sulphate of ammonia, if preferred in point of price. This mixture should be used in the same manner and quantity as the phospho guano, or other manures now employed for the cultivation of the canes."

Between the extremes of strong clays and light sands, every variety of soil is of course met with, and in the treatment of which no special remarks are here called for, except that besides the general character of a soil as revealed by its well-known agricultural capabilities, a more intimate knowledge of its nature as obtained by chemical analysis, is often of much service, particularly in ascertaining whether it needs liming or not.

Sandy soils, as already noticed, are frequently very deficient in lime, because all lime compounds are soluble, though to a small extent, and hence in course of time are washed out of such soils; but soils of a better kind are frequently crippled, so to speak, from the want of lime, which apart from its ameliorating influence in improving the soil generally, is directly re-

quired as a mineral plant food in comparatively large quantity by all cultivated crops. In such cases the addition of lime has a most beneficial effect, and we may thus obtain at small cost an improvement which more costly manures have failed to realize, for the reason that perhaps this one element only was needed to allow of the full capabilities of the soil being exercised. Even on lime soils, or those in which carbonate of lime prevails, the application of lime in some other shape is often of service, as for instance, sulphate of lime or gypsum to clover: in this case the sulphate is doubtless the effective agent. Gypsum is an inexpensive material, and might be freely tried upon clover layers when failing, or still better a mixture of gypsum and kainit, say two parts of the former to one of the latter, and used at the rate of 4 to 5 cwt. per acre. In cases of clover "sickness" this treatment is often of benefit, although not to be depended on as a remedy; there is in fact no manure which can be considered a remedy for it, the clover crop being particularly insensible, so to speak, to all artificial manure. It is a well-known and curious fact that clover will not yield a good crop when repeated at short intervals, but requires the land to "rest" from it before it can be successfully repeated —no manure having been yet discovered that will dispense with this interval of time. It would appear that certain organic products are requisite for its growth, which are furnished only in the soil, and which require

a considerable time for their development. The practice of applying the farmyard manure to the clover crop, as adopted in some districts, often has an excellent effect.

On the Use of Compound or Special Manures.

As regards the further admixture of the various manurial materials in the preparation of special manures, that is, manures for particular crops or kinds of crops, the following recipes, in addition to those above given, are offered, either to farmers who desire to try their hands at the preparation of their own manures, or to those who manufacture on the larger scale for sale.

It will be noticed that the mixing of dry materials only is here treated of, the use of acid for dissolving phosphates, &c. having been sufficiently explained under "Making."

On the smaller scale, the operation of mixing such materials is best performed by turning them out of their bags on a clean surface (as a boarded or asphalte floor) in a flattened heap in successive layers, afterwards putting the whole through a screen, cutting the mass vertically with the shovel. The screening may have to be repeated to obtain a sufficiently complete admixture of the whole of the materials (upon which

much of the efficacy of the manure depends), the lumps being broken down with the back of the shovel. The "disintegrator," as already mentioned, is used for this purpose on the larger scale, but even this machine, although it thoroughly incorporates the portion it contains at one time, offers no provision for the due apportionment of the components throughout the whole of the bulk, and to secure which much care is needed, and to the neglect of which the disappointment sometimes experienced in the composition of the completed mixture is generally attributable.

One of the most concentrated artificial manures is a mixture of equal parts of superphosphate and sulphate of ammonia, and although necessarily costly, will be found when carefully employed even superior to Peruvian guano. For corn on strong land this mixture should be used at the same rate as guano. On lighter land less ammonia may be used, say one-third sulphate of ammonia and two-thirds superphosphate. For spring use we may use equal parts of nitrate of soda and sulphate of ammonia in place of the latter alone. See p. 104.

The same mixtures form valuable dressings for grass land, and although it is a too common practice to grudge a manure of this kind to grass land, it will in the majority of cases yield a good return.

Peruvian guano may be substituted for the sulphate of ammonia (as mentioned under mineral superphos-

phates) if preferred, but greater care will be requisite in mixing, and more precipitated phosphate likely to be formed. See p. 108.

For turnips and swedes on good soils, with farmyard dung, or even without it, mineral superphosphate is often sufficient to give a good crop. On poorer soils, or when less dung is available, or a superior crop desired, a good dissolved bone, such as fully described under that head, is more suitable, and the extra cost will, if the season is at all favourable, give an ample return. Turnip manures are often made with mineral superphosphate and fine bone dust, and will succeed well on certain soils, but as a rule a manure in which the bone has had the benefit of the acid, even though not dissolved, is to be preferred. Some of the bone meals and steamed bones form admirable mixtures for roots. In such cases one might add $\frac{1}{4}$ fine bone or meal to $\frac{3}{4}$ mineral superphosphates.

For mangolds the following mixture will be found an excellent manure :—Dissolved bones 3 parts, guano 1 part, or sulphate of ammonia $\frac{1}{2}$ a part, and common salt $\frac{1}{2}$ a part. It should be used at the rate of 4 to 7 cwt. per acre, according to the weight of crop the soil may be expected to produce. For clover see p. 115.

For potatoes I should recommend 3 parts, dissolved bones, $\frac{1}{2}$ part kainit, $\frac{1}{4}$ part sulphate of ammonia, or $\frac{1}{2}$ part guano. The kainit supplies the potash largely required by this crop, and which is sometimes recom-

mended as a specific against the potato blight; but without going so far as this, it may be accepted as a fact that this crop is particularly benefited by potash manures, and rendered less liable to the disease.

It need hardly be said that parts mean equal weights, whether pounds, hundredweights or tons.

It may be added that many of the special manures now in the market are of excellent value, being prepared on sound principles, and found by careful practical trial to be well adapted for the kinds of soil for which they are recommended, and in such cases we cannot do better than purchase them, when it is not desired or convenient to mix them oneself. On the other hand, we should be particularly careful in buying such manures that they are as good as represented, as some unscrupulous dealers make most of their profit out of these special manures, many of which are special manures only in name, as it is said of dishonest tea grocers, who make a few canisters do duty for a long list of teas.

Having got our manure, the next thing is how to apply it to the best advantage, since, as is well known, much of the virtue of a good manure may be lost by careless application, while on the other hand a comparatively inferior manure may be made to yield better practical results than could be expected from its composition, by care in this particular. A thorough dissemination of the manure with the soil at the places

where it is likely to be most beneficial to the plant, is the point to be attended to—the condition of the manure being of course such as to allow of such dissemination. The following passage from my "Agricultural Chemistry," page 278, in speaking of the mechanical properties of manures may here be quoted:—"The value of these properties is discovered more particularly in the application of manures which cannot be properly carried out without them, and so important is it that the fertilizing elements of manures shall be so placed in the soil as to allow of their exercising their full effect on the plants of the crop, that a good mechanical condition will often determine the practical superiority between two or more manures otherwise much alike. In fact, a manure which is chemically deficient, may, by possessing excellent qualities in this respect, actually gain a character for superiority in the field; thus showing, not that chemical properties are of secondary importance, as we might at first sight conclude, but that the physical characteristics above spoken of are a necessary adjunct to allow of their due effect on the land, and without which a manure will compare unfavourably with others in which this point is better attended to."

The best conditioned manures generally require some little attention before application, as from the tendency of the phosphates to adhere, even by the weight of their bags on one another, their contents are

apt to consolidate. This caking or lumping, however, needs but the least breaking down with the back of the shovel when the bags are turned out, and should not be confounded with the crude undisintegrated lumps observable in badly made manures. The plan of mixing the manures when about to be used with sifted ashes is a good one, and should always be adopted if possible.

On the important point, whether it is better to drill the manure with the seed or sow broad-cast and harrow in—it appears that for roots the former is the better plan—as proved by carefully conducted experiments made on the large scale by a friend of mine with this object in view: when a heavy dressing is applied, however, it may be preferable to drill a portion and sow the remainder broad-cast. For corn crops, the plan of sowing broad-cast is generally preferable. It need hardly be added that when the water drill is used, less care in the preparation of the manures suffices.

Strange as it may seem, there is every reason for believing that the soluble phosphate of our manures again becomes insoluble before being taken up by the plant, that is to say, it is precipitated naturally in the soil.

The nature of this precipitated phosphate will be understood by reverting to the experiment described for showing the nature of soluble phosphate; we there

perceived that soluble phosphate was invisible in water, and in order to make it visible, we added soda, or some other alkali, the effect of which was to precipitate it, or render it *insoluble,* when it appeared as a gelatinous creamy solid. The phosphate of lime so separated (than which we can imagine nothing more acceptable to plants in the way of a phosphatic food) is the precipitated phosphate above mentioned, and differs from ordinary undissolved phosphate by having its particles in a *chemically divided* state—that is to say, reduced to a degree of minuteness infinitely surpassing anything obtainable by grinding.

Soluble phosphate is known to become changed into this gelatinous or precipitated form after remaining a short time in the soil, owing to the carbonate of lime, organic salts, oxide of iron, &c., there present, exercising in a slight degree a similar action to the soda which we used, and it is no doubt the form in which the soluble phosphate supplied in manures is fed upon, so to speak, by the rootlets of plants. This can be shown by mixing a portion of superphosphate with a much larger quantity of moist soil, and leaving it for a short time, when it will be found that no soluble phosphate can be extracted from it by water. That solubility is not essential to the practical value of the phosphate supplied to plants, is also shown in the case of rich garden mould, which contains an abundance of highly assimilable phosphates, as proved by the fact of

all kinds of produce thriving in it, and which yet does not contain a particle of soluble phosphate; the fact being that all organic matter on decay liberates the phosphates and other mineral constituents it contains in a chemically divided state, which, as above mentioned, is the form in which it is reassimilated by plants, and which circumstance I think throws light on the practical value of farmyard dung and nightsoil manure, as better fertilizers than can be explained by the soluble phosphate present in them.

Precipitated phosphate is therefore as valuable as soluble phosphate, except in so far that it has lost the power of spontaneous diffusion possessed by the latter, and this lessens its commercial value, since it is this condition of solubility which it is wished to secure, and for which we chiefly pay in buying superphosphates. &c. Solubility is to be preferred because it affords the means of getting our phosphates chemically disseminated in the soil, that is, incorporated with it in a much more perfect manner than is attainable by any mechanical means, and to which circumstance the value of superphosphate as a manure is mainly due. In other words, when we apply superphosphate to our land the soluble phosphate soaks into the adjacent soil, and there becoming precipitated, is spread over a large surface, whereas if we apply precipitated phosphate at once, it remains where we put it, and however much it may be stirred in, a much smaller bulk of the soil is

benefited by it, and the roots of the crops will have more limited area to work upon.

In conclusion it should be added that a fine condition of the soil, as obtained by careful cultivation and management to secure the benefit of frost and dry weather, &c., adds much to the efficiency of manures —in fact, is tantamount to an additional dressing of manure—a smaller quantity thus supplemented being more effective than a larger quantity on a roughly prepared soil, where much of the manure gets buried under clods out of the reach of the plants. By attention to these points it is quite possible to make 3 or 4 cwts. per acre, do the work of 6 or 8.

Finally, we should always bear in mind that it is bad policy to starve our soils, as it is our live stock; it is quite as much as we can expect in the one case as the other, for them to make saleable produce out of raw materials; but to expect them to do so out of nothing, or with insufficient materials, is almost as absurd as it would be to expect a bricklayer to make good progress with his work, at the same time keeping him short of bricks; yet this is what many farmers seem to be always trying to do. We may depend that the full benefit to be derived from the soil, and from our live stock also, can only be realized when its productive power is allowed full play by the plentiful though judicious supply of food.